JOHNS HOPKINS HOSPITAL.

Reports and Papers

RELATING TO

CONSTRUCTION AND ORGANIZATION.

No. 5.

ON HEATING AND VENTILATION.

Washington, D. C., Feb. 12th, 1878.

Mr. Francis T. King.

President of the Johns Hopkins Hospital.

Dear Sir:

In accordance with your request I have the honor to submit herewith certain recommendations with regard to the methods of heating and ventilation to be employed in this Hospital. In previous communications I have alluded to certain general principles which should govern the decision of the Trustees upon this subject, although I have not made specific recommendations,—but the time has now come when the methods to be employed must be decided upon for a majority of the buildings.

For the most important of the buildings in a sanitary point of view, namely, the common wards, this decision need not be final, as I shall presently show, but in the main Administration building and Pay wards, and in the Nurses' Home, whatever plan is adopted must be, in the

main, permanent, since changes after these buildings are constructed will be difficult and expensive.

Ventilation.

The problem to be solved may be roughly stated as follows, *i. e.*, to insure that in all parts of each room at all times the air shall be as free from dangerous impurities, or perceptible odors, as the external air in the central garden is: that this shall be done when the temperature of the external air is at zero without causing discomfort to the occupants of the rooms from cold, heat, or draughts: that it shall be done when the external temperature is 100° F. and there is no wind, and that it shall be done whether the external air be dry, or loaded with moisture, whether it be perfectly motionless, or blowing a gale from any point of the compass.

To any one who is practically familiar with the subject of ventilation, and with the many failures which have followed attempts to secure it in large and complicated buildings, this seems difficult enough. Were this the whole of the problem, however, it could be answered, since all that I have mentioned is possible to modern engineering. But another set of conditions is to be added. All this *must* be done at a reasonable cost for construction and maintenance, and it *should* be done as cheaply as possible; in part because every dollar used for this purpose prevents the doing of something else which is also, though perhaps not equally desirable, in part because one of the greatest services which this Hospital can render will be to demonstrate, for the benefit of other Hospitals less richly endowed than itself, the system of heating and ventilation which is the cheapest and simplest for producing the effects desired.

Now under the last conditions it is impossible to meet the indications of the problem; we can only approximate to the results desired, and beyond a certain point, what is

gained in one direction must be lost in another. If these conditions be examined it will be seen that economy may be attempted, by lowering the standard of purity of air to be maintained, and by providing for only average conditions of air as to moisture and winds, as for instance, if we undertake to secure the results furnished by an ordinary private house. To judge of the merits of this proposition it is desirable to fix upon some standard of purity to be obtained, and to have some definite idea as to what may be considered a reasonable cost both as to establishment of apparatus and as to maintenance.

Pure and Impure Air.

First, as to the standard of purity. By pure air in this connection is meant the great mass of the air surrounding the buildings, and not a fixed chemical standard. This air may at times contain various impurities derived from those parts of the city over which it has passed, but we call it pure as compared with that within the buildings which is to be diluted or displaced. After this air enters the buildings, it will be rendered impure by gases and vapors and by suspended particles, liquid or solid, derived from the bodies of the occupants,—from food, medicines, excretions, and decomposing filth of various kinds. Some of these impurities are offensive to the sense of smell, rather than dangerous, as for instance, the odors arising from fresh intestinal discharges,—others are dangerous to health and life, although not specially offensive, while some are both offensive and dangerous.

Some, such as those derived from respiration, are constantly produced and present, others, such as the odors from fresh excretions, or from the exposure of sloughing wounds in dressing are only occasional and temporary.

It must be remembered that a system of dilution and removal which will be satisfactory for the regular and constant impurities will be temporarily insufficient to remove

at once these occasional irruptions of offensive gases which, however, are, fortunately, not specially dangerous. From about 6 to 9 A. M., in winter, a hospital ward, especially if filled with surgical cases or with patients confined to their beds, is liable to various gaseous contaminations—and will present a very perceptible odor, due to food, medicines, excretions, discharges, etc., and during this time it is very desirable to have the means of flushing the ward with a large quantity of fresh air—so large that in ten minutes all odor shall have disappeared. This cannot be done by any system of aspiration unless it be made of such size and power as would involve an unreasonable cost for fuel at all other times.

The dangerous impurities to be dealt with are probably for the most part due to organic matter, in the form of dust or vapors. In rooms, occupied by healthy persons, or by cases of disease not specially affecting the skin or mucous membranes, such as disease of the heart, paralysis, chronic rheumatism, etc., the organic matter is usually present in quantity proportioned to the amount of Carbonic Acid present, and hence the amount of Carbonic Acid present may be taken as an index of the amount of the organic matter. Carbonic Acid in the quantity in which it is present in ordinary living rooms and in Hospitals is neither unpleasant nor dangerous, for under such circumstances it seldom exceeds 1 per 1,000, while there must be about 5 per 1,000 before the presence of this gas produces any special effects.

I must also insist upon the fact, well known to all physicists and chemists, but usually unknown to pseudo-scientific writers on ventilation, that *Carbonic Acid is equally diffused throughout the room, it does not collect near the floor, and the fact that its specific gravity is greater than that of air at the same temperature has nothing whatever to do with questions of ventilation in a Hospital.**

* If any reader doubts this, he is advised to study the law of the diffusion of gases, and also to consult the following, viz: Lassaigne, J. L., Recherches

The only interest which Carbonic Acid has for us in the present connection is, that within certain limits its quantity may be taken as a measure of that of really important impurities, and it is almost the only available test for this purpose.

As yet we have no accurate means of testing the amount of organic impurities in air, in fact we have very little precise information as to their nature, and especially as to those which may exist in the form of vapor. We have, however, good reason to believe that they are produced in greater quantity by the sick than by those that are well, and also that they assume specially dangerous forms in Hospital Wards. Keeping these points in view, what should be our standard of purity of the air?

Standard of Purity, and Quantity of Fresh Air Required.

As I have elsewhere explained, perfect ventilation implies that a man shall inhale no air or suspended particle which has recently been in his own body, or in those of his companions. To ensure this, all the air in a room must be made to move uniformly throughout the room in one direction so that there shall be no possibility of eddies or currents, and in most cases this direction must be directly upwards. All usual systems of ventilation aim, not at this theoretical perfection, which in cold weather is very costly, but at rapid and uniform dilution of the foul air, leaving some of it to be rebreathed. The amount of dilution required for satisfactory ventilation is expressed in terms of the Carbonic Acid present. In the external air the amount of Carbonic Acid present is about 4 parts in 10,000. If the proportion of Carbonic Acid in a room does

sur la composition que présente l'air recueilli à différentes hauteres dans une salle close, [etc.]'' Bull. de l'Acad. Roy. de Méd., XI. Paris, 1846, p. 1240. and Thompson: ''Experiments on the accumulation of foul air in ill-ventilated rooms.'' Indian Med. Gazette, 1869, IV, p. 205.

not exceed 6 parts per ten thousand, or 7 parts when gas is burning, there will be no perceptible odor, and we may say that such a room is well ventilated. Even in such a room a case of scarlatina or small-pox, or surgical erysipelas, or hospital gangrene, would be dangerous to other inmates, because a single particle of organic matter, such as convey these diseases, cannot be diluted, and a single particle may do the mischief. Also in such a room a case of profuse suppuration as from an extensive burn, or a case of sloughing cancer, will produce offensive, if not positively dangerous odors; and it is therefore desirable by a proper system of classification to keep all such cases out of the common wards.

By attention to this, to cleanliness everywhere, and to providing against the possibility of the entrance of sewer gases we can with a great degree of certainty prevent the presence of any dangerous impurities in the common wards, and may therefore rest satisfied with the ordinary method of dilution to the standard above indicated.

How Much Fresh Air is Required?

The estimates of quantity required, made by Physiologists and Engineers down to quite recent times, have been too small, and the demands have steadily increased. Thus the specifications for the Lariboisiere Hospital called for a maximum supply of 1,400 cubic feet per hour per bed, while recent French estimates call for from 2,400 to 5,300 cubic feet per hour. The specifications for the Friedrichshain Hospital at Berlin call for from 2,500 to 3,000 cubic feet per hour per bed.

The most satisfactory investigations on this subject are those made by Dr. De Chaumont, who takes as a standard of purity that condition of air in a room occupied by several persons, as for instance in a barrack dormitory, in which to a person entering from the fresh outer air, there is no perceptible odor.

By a number of experiments, which are confirmed by some made in this vicinity, to which I shall presently allude, he has shown that when the proportion of Carbonic Acid in such a room does not exceed 6 parts in 1,000, the air will not be perceptibly impure, and that this, therefore, may be taken as the standard limit.

A little calculation will show, that to keep the proportion of Carbonic Acid down to this ratio, about 3000 cubic feet of fresh air per hour per man must be introduced and distributed. It is important to remember, that this amount is not affected by the amount of cubic space allowed each occupant, where the occupation is permanent. Whether each man has 250 or 2500 cubic feet—the amount of fresh air required for dilution to a certain standard will be the same after a very short time.

Undue importance has been given by many writers to this question of cubic space in hospital wards. If the necessary amount of fresh air be supplied and properly distributed, so that unpleasant currents of air are avoided, cubic space is of minor importance, and although 1000 cubic feet should be the minimum allowance to each person, yet the amount of it to be allowed depends on other considerations than those of ventilation.

I habitually use a somewhat higher standard than that given by Dr. De Chaumont—viz: One cubic foot per second per man as the minimum allowance, a quantity easily remembered, very convenient in calculating areas of registers and flues, and, in my opinion, not excessive.

For persons in health, and for the majority of cases of disease and injury, I think this quantity of one cubic foot per second per man, will be found sufficient to keep the rooms free from all odor or dangerous impurity, except under special circumstances referred to above, and I therefore recommend that this be the standard minimum supply for all buildings in the Hospital, except the Isolation wards and Pay wards. The Isolation wards are designed for cases of disease which are not directly contagious or spe-

cially dangerous, but in which rapid tissue-degeneration is going on, and large quantities of organic matter are being thrown off; or for cases which would be offensive to other patients. For these wards the average quantity of air-supply should be two cubic feet per second per bed. In the Pay wards, as also in the Isolation wards, each patient has a separate room, and more cubic space than in the common wards. This excess of space and of angles and corners makes it somewhat more difficult to secure proper distribution of the air, for which reason, as well as to secure proper heating, I would advise that the normal supply for each room be fixed at one and a half feet per second.

It will also be desirable that, for all the wards, the ducts and flues shall be so arranged that the average quantity of air-supply above specified can be at least doubled whenever it is desired, as it will certainly be for a short time at least once a day.

In this connection I invite special attention to the quantity of air-supply, and the results obtained, as shown in the reports from two Hospitals given hereafter in this paper.

Effects of Moisture in the Air.

The amount of dilution by fresh air which is required to keep a ward free from perceptible odors, varies with the amount of moisture which the air contains.

It is much more difficult to secure satisfactory ventilation when the air is loaded with vapor; in part, as will be shown, by experiments to which I shall presently refer, because the usual aspiration systems do not work well under such circumstances; in part, because the amount of air required is absolutely greater. So much is this the case, that when the temperature and dew point of the external air do not vary greatly, it is possible to calculate from hygrometric data only, in much the same way as

from Carbonic Acid determinations, as to whether the ventilation of a room is satisfactory or not.

In this connection two papers, by Dr. De Chaumont, presented to the Royal Society, will be found of interest. He concludes that for England the difference between the wet and dry bulb thermometers ought not to be less than 4°, nor more than 5°; that the amount of vapor should not exceed 5 grains per cubic foot at a temperature of 65°, and that the percentage of humidity should not exceed 75.

"An increase of one per cent. of humidity has as much influence on the condition of an air space (as judged of by the sense of smell) as a rise of 4.18° Fahr."

He illustrates the methods of calculation by supposing a room at the temperature of 60° F., with 88 per cent. of humidity, or 5.1 grains of vapor per cubic foot.

"Suppose the external air to be at 50° F., with the same humidity, 88 per cent., this would give 3.6 grains of vapor per cubic foot; to reduce the humidity in the room to 73 per cent., or 4.2 grains per cubic foot, we must add the following amount of external air:

$$\frac{5.1 - 4.2}{4.2 - 3.6} = 1.5,$$

or once and a half the volume of air in the room. If the inmates have each 1000 cubic feet of space, it follows, that either their supply of fresh air is short by 1500 cubic feet per head per hour, or else that there are sources of excessive humidity within the air-space which demand immediate removal."*

The figures given by Dr. De Chaumont do not apply in this country where the atmospheric conditions are so different as regards humidity that no calculation for heating, based on English data, will hold good; but the general principle laid down applies here as well as there at certain seasons of the year, and should be borne in mind by those who are to make observations and experiments on this subject.

* Van Nostrand's Eclectic Engineering Magazine, December, 1877, p. 496.

In this connection I would call attention to a very interesting and instructive paper, by Mr. Robert Briggs, of Philadelphia, on the relations of moisture in the air to problems of Heating and Ventilation,* which is the clearest exposition of the subject with which I am acquainted.

Starting from the well known fact that in cold weather it is necessary for comfort to heat the air in occupied rooms, in the United States, at least ten degrees higher than would be required in England, he shows that this is due to the absence of moisture in this country. The percentage of humidity in a Hospital ward in cold weather often does not exceed 25° in this country, an amount, according to De Chaumont, which is entirely insufficient, but which in itself does not seem to produce any ill effects.

Mr. Briggs shows the great difficulties, amounting in fact almost to an impossibility, in the way of obtaining such a degree of humidity in inhabited rooms, in this country, as that recommended by De Chaumont, and if it could be done, he thinks it would be unhealthy, because of the great change which a person would experience in passing from such a room into the cold dry external air. Judging from the results of the Turkish or steam bath on the bathers, and more especially on the attendants—it is doubtful whether the ill effects would be as great as Mr. Briggs supposes, for the attendants in these baths, who remain daily from five to six hours in the superheated atmosphere, saturated with the moisture of these rooms, do not appear to be specially liable to pulmonary diseases.

In the same paper, reference is made to the fact that in rooms heated by warm, dry air, the sensations of discomfort which many persons experience, such as headache, etc., may be relieved by the addition of a small quantity of moisture to the air, for instance, about, 5 per cent.

At first sight this would seem to prove that the uncomfortable sensations were due to absence of moisture, but

* On the relation of Moisture in the Air to Health and Comfort. By Robert Briggs.—Jour. of the Franklin Institute, Jan. and Feb. Nos., 1878.

nearly the same amount of vaporization is desirable in air heated from any temperature and therefore varying greatly in the absolute percentage of moisture which it contains. Moreover, in very dry and warm climates, such as that of Arizona, these uneasy sensations are not present.

It seems to me probable that in the majority of persons these sensations are due to insufficient supply of fresh air rather than to want of moisture, and that the effects of vaporization in relieving them may, in part at least, be explained as follows:

In a room heated by hot air from a furnace, or set of steam radiators, all the fresh air for the chamber usually passes over the heated surfaces, and enters the room at an average temperature of 180° F. If the quantity of fresh air required for satisfactory ventilation be admitted at this temperature, the room soon becomes unendurably hot, and to prevent this the amount of incoming air is diminished by partially or entirely closing the register.

Now, if in front of the register, be suspended a porous earthen vessel containing water, or wetted cloths, or a large sponge saturated with water, rapid vaporization is the result, and a large amount of heat is expended to effect this.

The result is that the incoming air is cooled and a much larger quantity can be admitted without discomfort. In rooms and passages heated by direct radiating surfaces such as steam coils, this feeling of discomfort is very common, and is mainly due, I think, to the insufficient ventilation which is usually found in such places.

I have never myself found it to occur in rooms having an ample supply of air at a proper temperature, however dry the air may have been, but Mr. Briggs and others state that they have so found it, and under such circumstances I can suggest no satisfactory explanation.

Supply and Distribution of Air.

In the common wards it is proposed to supply from one to two cubic feet of air per second per man, which implies the removal of a like quantity, and the ducts and openings required for this purpose must be so arranged as to secure the most thorough distribution possible of the fresh air, and consequent dilution of that which is impure.

This arrangement should depend on the following facts:

1st. The velocity of the incoming air should not exceed two feet per second.

2nd. The openings for ingress of air should be numerous and scattered, in order to secure rapid distribution. I should prefer to have an opening for each bed, and certainly not less than one opening to two beds should be provided. In the first case, the area of clear opening in the register should be 100 square inches, in the second, it should be a little over one square foot.

3rd. Air has a strong tendency to adhere to surfaces across which it passes. This law is too often overlooked in arranging systems of apertures. If air enters a room at or very near the floor, in a horizontal direction, it will adhere to the floor, forming currents upon it almost like water, and will by no means rapidly rise and diffuse. If it enters the room through a register in the floor near a wall —it will adhere to the wall and flow up along it until it reaches the ceiling. If the register be in a corner, the air currents will adhere to the adjacent walls almost as if they were passing up a tube.

There is some difference of opinion as to the proper position of fresh air registers, and it must vary according to the size and purpose of the room. In a large room in which the centre of the room is occupied, as in a legislative hall or place of amusement, the registers must be in some way distributed on the part occupied, but in a Hospital ward—where the centre of the room is nearly empty, and the occupants are for the most part along the sides,

the usual arrangement of registers in the walls seems preferable.

General Morin advises that the registers should be placed near the ceiling to avoid unpleasant draughts, and for the same reason almost all the various patent ventilators for the admission of fresh air directly from the outside without warming it, are placed in the same position.

When the air is warmed before admission, this position of the registers causes considerable loss of heat, as has been found by experiments presently to be referred to, and it requires an objectionable amount of flues in the wall. It also requires more force in the aspirating flues, as the ascensional power of the heated air is lost in the room, and the currents adhere to the ceiling, and it should be condemned under all circumstances except in what is known as Barker's patent system—in use in the Hospital of the University of Pennsylvania—where it would certainly be an improvement.

The greatest objection to this position of fresh air registers in an Hospital Ward, is that it prevents control of the temperature in a given part of the ward, (for instance, for two or three beds), as all parts of the ward on the same horizontal plane must be of the same temperature. It is often very desirable to be able to lower the temperature in one part of the ward without affecting the rest, and if the fresh air registers are behind or near the head of the bed, it is easy to do this.

Some saving in heat is effected by removing the hot air flues from the outer wall—and placing them in the centre, as is done in the Friedrickshain Hospital, at Berlin—but this also destroys local control of temperature, and is not to be recommended.

I have seen the fresh air openings placed directly under the head of the bed, as in the new obstetrical pavilion of the Charité Hospital, at Berlin, but I do not think this has any special advantages, while it ensures that all the air

has been in contact with bedding before it is breathed—which is not desirable.

It is important that the fresh air openings be so arranged that it is impossible for the patients to close them. The registers in the wards, therefore, should not be movable, and the valves for controlling the supply of air should not be accessible to the inmates of the ward. There should, however, be at each register, and under the control of the nurse, the means of regulating the temperature of the incoming air, to a certain extent, by admitting more or less external air which has not passed over the heating surfaces. This will be desirable whether hot water or steam be used.

As to the foul air registers or openings, theoretically, they should be of somewhat less area than those for fresh air, but practically, they may be nearly or quite the same because of the quantity of air which finds admission directly through the walls. In brick buildings, such as those of this Hospital, the amount of air which may pass directly through the walls is, as shown by Pettenkoffer and others, much larger than is usually supposed, and is no small addition to our means of ventilation.* It is very undesirable to place foul air flues in the external wall of a Hospital ward, and especially if the air in these flues is to pass upward. It is only possible to make such flues work well by applying special power to them, at an increased expense.

The register openings should have large spaces, and be as little encumbered with louvres or ornamental iron work as possible, for both in these and in the ducts with which they are connected, friction should be reduced to a minimum.

If but one set is to be provided, and this is enough for rooms for persons in health, it is better that they should

*Upon this subject of the permeability of building materials, consult two papers by Dr. E. Schürmann in the 3rd and 5th Jahresberichte der Chemischen Centralstelle für Oeffentliche Gesundheitspflege in Dresden, 1874 and 1876, and "Ueber natürliche Ventilation und die Porosität von Baumaterialen von C. Lang. Stuttgart, 1877. 8°."

be placed near the floor. An ordinary open fire-place and chimney, even without a fire in it, is the best of all foul air systems in a room heated by indirect radiation. In a sick ward, however, there should be two sets of foul air ducts—one above, and the other below the ward, with two sets of registers to correspond.

In one-story wards, such as the common wards of this Hospital, the upper system may be one of ridge ventilation, and the ceiling should be slightly coved or arched. The lower system should consist of a central foul-air box of galvanized iron suspended from the centre of the ceiling of the basement beneath the ward—and passing to the aspirating chimney of the ward. The velocity of the air in this main trunk should be about four feet per second, hence for twenty-four beds it should have at the end nearest the chimney an area of about eight square feet, and may diminish to not less than two square feet at the farther end. The foul air registers may either open directly into this duct, along the central line of the floor of the ward—as in the Barnes Hospital, or what would probably be preferable, they may be placed under the foot of each bed and connect with foul air ducts which should lead to the main duct and enter it at an angle of forty-five degrees properly rounded.

Which ever plan be adopted, the amount of clear opening in each register and duct should gradually increase towards the south end of the wards, and the total difference between the extreme northern and southern openings should be about 25 per cent. The area of each lateral foul air duct should be about one foot square, and these it will not be worth while to vary much, if any in size. All ducts should be accessible for cleansing purposes, and this also applies to the heating coils or surfaces.

These points will be further discussed in speaking of the arrangements for the several buildings.

It should be remembered that in a system of ventilation by aspiration the greatest obstacles arise from doors, win-

dows, and other openings than the fresh air flues. In the wards, and service-rooms connected with them, it is especially desirable that the doors shall be kept closed as much as possible.

To secure this, they should be self-closing, but they must also be easily opened. I believe that the best plan will be to have them double-hung, self-closing by springs, and closing as tightly as possible. Doors thus hung should be as light as possible to avoid strain, and should not be liable to be affected by moisture. It is possible that they might be constructed of light galvanized iron, hollow, the interspace being filled lightly with felt. If of wood, they should be as plain and smooth as possible. Throughout the Hospital, the water closets, bath tubs and sinks, are arranged around special ventilating shafts which contain the soil and water pipes and are heated by high pressure steam coils. By this arrangement, by taking care that no pan or hopper closets, and no bell or D traps are employed in the buildings, and by securing thorough ventilation for all sewers, soil pipes and traps, I think there need be little fear of any nuisance or danger from this part of the service.

So far as it is possible to foresee, ventilation should have only necessary contaminations to deal with. The unnecessary ones should be prevented, and it is surprising how many will be found unnecessary when carefully examined.

Heating.

Before discussing the methods for obtaining and distributing the amount of air-supply considered requisite, it is necessary to speak of the methods of Heating.

During at least six months in the year artificial warmth must be supplied in this Hospital, and arrangements must be provided for doing this, when the external temperature is as low as zero F. The first question to be decided is, as

to whether this shall be effected solely by warming the air which is to be introduced by causing it to pass over heated surfaces in the basements or cellars of the buildings to be warmed, being what is known as the method by indirect radiation ; or by placing the source of heat in the room to be warmed, and allowing the air to enter cold, being what is called the method of direct radiation ; or by a combination of these two methods.

Each method has its own special advantages and disadvantages, and its own enthusiastic advocates.

From the physiological side of the question, it is no doubt better that the air entering the lungs should be at a temperature of from 45° to 60° F. rather than from 70° to 80° F. It is not true, however, that fresh air at 70° F., the wet bulb of the hygrometer showing a temperature of from 50° F. to 64° F., has any specially evil or debilitating effect, as is evident from a consideration of the effects of many of our pleasant spring and summer days. It is rather a question of moisture than of temperature.

It is also true that a system of heating which will keep the feet warmer than the head, is preferable to a system which gives the opposite result. Now, if the method of indirect radiation, or heating by warmed air, be exclusively used, the head will generally be in a warmer atmosphere than the feet. Methods of heating which warm the floor and lower parts of the walls are therefore more comfortable, and in so far better, than relying on warm air alone. On the other hand, if the air is to be introduced cold, it is more difficult to secure the proper quantity and distribution without liability to unpleasant draughts and currents, the heating apparatus in large buildings cannot be concentrated, and if floors and walls be warmed, in sudden changes of temperature, it is more difficult to provide for them, and especially for a rapid rise in temperature.

The apparatus for heating by indirect radiation is simpler, and if it gets out of order can be adjusted without

the presence of workmen in the rooms to be warmed; it is, in my opinion more economical, although positive data are wanting on this subject, and if compelled to use but one system it is the one which I should prefer in most cases.

A combination of the two systems will be better than either alone, and the combination should be varied in the several buildings as I will explain hereafter.

Hot Water or Steam.

The next question in regard to heating is, as to whether hot water or steam should be employed for this purpose.

In previous communications I have expressed a preference for the use of hot water apparatus with large heating surfaces of a comparatively low temperature, i. e. from 100° F. to 160° F. My objections to steam heating as I had seen it, were that the air is generally overheated, that the various valves and other contrivances for mixing cold air with the superheated air in order to produce the proper temperature are generally unsatisfactory, the air escaping in alternate puffs of cold and hot air, that, unless very carefully set, there is liability to annoyance from noises in the pipes due to condensation, and that more constant and skilled supervision is necessary with the apparatus.

From practical trial with the hot water method, I am perfectly sure that for heating purposes it is entirely satisfactory, and is probably cheaper than steam, and for proof of this I refer to the account of the heating of the Barnes Hospital, which I will quote presently.

My attention has been called recently, however, to a very successful application of steam heating in the new wards of the Boston City Hospital, according to the plans and under the direction of Dr. Cowles, the Superintendent. From information furnished by Dr. Cowles, and from my own observations, I believe that this method gives satisfactory results; results so far as temperature and ventilation

are concerned, as good as, but no better than the hot water system.

As the wards are the most important part of the Hospital, I am therefore of the opinion that the heating can be satisfactorily effected by either hot water or steam, but I believe that the hot water apparatus is more simple, and, upon the whole, less expensive, and I therefore advise its use in the wards. In some of the other buildings steam would probably be less expensive than hot water.

Whatever form of heating apparatus be adopted, it has been considered advisable that the boilers shall be divided into two gangs, one to be placed in the kitchen building, and the other in the Nurses' Home, and these buildings have been planned accordingly, and provided with chimney shafts of the necessary capacity.

This has been done in part to obtain a shorter, quicker and less complicated circulation, and in part to increase facilities for the storage of coal. No steam boilers however, should be placed in the Nurses' Home.

In previous reports I have given various theoretical speculations with regard to the methods of ventilation, and have pointed out that the difference between these methods is largely a matter of dollars and cents, and also that there are no satisfactory data in existence to determine this difference with that precision which is desirable. I propose now to give some positive data upon which I shall base my recommendations. The first is an extract from a report made by Surgeon D. L. Huntington, U. S. Army, to the Governor of the Soldiers' Home, in Washington, upon the heating and ventilation of the Hospital of that Institution. This report has not been printed, and I owe the privilege of making use of it to the special courtesy of the Board of Commissioners of the Home.

The statements made may be considered as absolutely reliable and correct,—many of the experiments of which results are given, were made at my request and for the express purpose of settling certain doubtful points, and Dr.

Huntington's care and accuracy as an observer and reporter are of the highest order.

"The Barnes Hospital at the Old Soldiers' Home near Washington, is a brick structure, consisting of a central executive building 52 by 45 feet, with basement, three stories and Mansard roof—two wings each 64 by 29 feet, basement, two stories, and Mansard—and two end towers each 24 by 46 feet, with same stories and elevations as the wings. The total amount of cubic space to be heated is about 310,000 cubic feet.

"The heating is effected by a low temperature hot water apparatus consisting of two tubular boilers, each 9 feet long and 42 inches in diameter, with connecting mains, pipes and coils.

"The heating coils, composed of cast iron pipe are placed in brick air-chambers in the basement, at the sides between the windows. At the point of entrance of the supply pipe to each coil is a valve by which the supply may be diminished to any degree, and the temperature of the coil regulated accordingly.

"From above the coils pass the flues for fresh air supply. These flues are of Terra Cotta pipe built into the walls. In the lower wards the flues are so arranged that the fresh air can be admitted either near the floor or near the ceiling. After a fair trial of each method it appears that the lower registers are to be preferred. When the air is admitted at the top the ward is heated unequally, a series of observations showing a difference of from 10 to 12 degrees between the floor and ceiling, and the patients complain of cold feet and discomfort, for which reasons the upper registers are not in use.

"The apparatus has given great satisfaction, has maintained a pleasant, even temperature of about 70° in the coldest weather, and permits of changing the temperature at any locality, easily and rapidly. Many such changes are made each day by the Engineer, to meet the varying circumstances of winds, changes of temperature," etc.

For purposes of description, the ventilation of the Hospital may be divided into (1,) the Natural Method; (2,) that by aspiration; (3,) that by propulsion; and, finally, by a combination of two or all the above methods.

I. Natural Ventilation or Perflation.

During the mild season of the year, from the month of May to September, both inclusive, the system of natural ventilation is mainly relied upon, and is found for the greater part of the time, to be sufficient. For this purpose all windows and doors are opened and kept so, continuously; fresh currents of pure air are poured through the building and a thorough ventilation secured.

On the hot stagnant days and nights, which not unfrequently occur in this latitude in early summer and in September, and when there is excess of moisture in the air, the ventilation is less perfect, though even then, the difference of temperatures between the interior and exterior of the building is usually sufficient to excite gentle currents, and create a change of air in the wards; but under these circumstances, it often becomes necessary to use artificial means to ensure a thorough ventilation of the building.

II. Ventilation by Aspiration.

At all times when the building is not thoroughly ventilated by natural means, fresh air is supplied by means of a vertical air-shaft, placed at the west of the Hospital building, at a distance of 74 feet. This shaft is 38 feet in height, with a diameter of 8 feet, open at the upper part and protected from the weather by louvre blinds. A large weather cock or vane placed above it turns a hood or cowl within the shaft, which tends to throw the current of air forcibly downward.

This shaft at its lower extremity connects with a brick air duct, 286 feet in length, which passes under the base-

ment of the building through its entire length, giving off at intervals, lateral branches, which pass into brick air-chambers, within which, are placed the coils connected with the heating apparatus, and finally terminating in Terra Cotta flues distributed to the several wards and rooms above. At its throat, this air duct is 8 feet high and 5 feet in breadth, but steadily decreases in size in its passage under the building, until at its extremity it is reduced to $2\frac{1}{2}$ feet in height by 2 feet width.

At the throat the amount of air passing into the duct and thence into the building is regulated and measured by folding-leaf doors, each leaf having a width of one foot and a height of 8 feet. This duct is kept perfectly clean and pure, and arrangements exist by which moisture may be supplied to the air in its passage.

The fresh air passes into the wards through accurately closing registers, each register having a practical area of one square foot of clear opening.

The quantity of fresh air supplied to the building by means of this duct varies, of course, with the direction and force of the wind, and with the greater or less activity with which the air in the interior is removed by natural or artificial methods of ventilation. Repeated anemometrical observations show the velocity of the air current through the throat of the duct, to range from 50 feet to between 8–900 feet per minute, the latter quantity during the prevalence of high Westerly or North-Westerly winds.

The removal of the foul air from the interior by aspiration, is effected by means of two large chimneys in the main or administration building; each chimney has an elevation of 96 feet, and 4′ 4″ x 5′ 8″ area, interior measurement, the area slightly diminishing as it ascends; each chimney is protected from the weather by a cap with open sides. A boiler iron flue, 2 feet in diameter, passes up the centre of each chimney from the basement floor to a height of 3 feet above the chimney cap; into these flues pass all the products of combustion from the several furnaces, range,

and other necessary fires, materially assisting the upward draft in the chimneys,—at the base of each flue is placed a grate for the purpose of producing an upward current, when from natural causes the chimneys fail to act; at the base of each chimney and at certain points in the elevation, are doors and apertures for access to the stacks and for the purpose of thermometrical and anemometrical observations.

Into these two chimneys open all the ducts which receive the foul air from the wards; these ducts, or foul air boxes, 50 feet in length, 3′ 3½″ wide and 12″ deep, are placed above and below each ward, and communicate above and below with the ward by means of accurately closing registers. These foul air boxes are lined with tin and are cleaned daily. In each ward and above each gas burner is fitted a 3 inch tube terminating in a funnel shaped cap, through which all air rendered unfit for respiration by the burning gas is discharged into the above mentioned ducts. Each ward contains 12 beds, is 50 feet long, 24 feet wide, and 15 feet high, containing 18,000 cubic feet.

The outlet registers in each ward communicating with the foul air boxes are ten in number, five opening through the ceiling and five through the floor; the openings of the upper tier are valve traps 12″ x 16″ each, with a practical area of 1.33 square feet; the openings through the floor are iron registers with closely fitting slats, protected by an ornamental grating: their dimensions are 14″ by 26″ with a practical area of 1.5 square feet.

Both fresh and heated air are introduced into the wards by a similar set of inlets; in each of the lower wards these inlets are sixteen in number, eight of them placed ten inches above the floor, and the other eight ten inches below the ceiling; the lower inlets are provided with registers with rolling slats and protected by ornamental iron work, and have an area 12″x18″; the registers of the upper tier are of similar style with an area of 12″x16″, but all, both lower and upper have the same practical area, viz:—one square foot. In the upper wards the inlets are eight in

number, similar in style to those of the lower wards, with a practical area of one square foot, and are placed ten inches above the floor.

The double set of inlets for fresh and heated air in the lower wards is arranged for experimental purposes, to determine, if possible, the best position for warm air registers, heating and ventilation.

The ventilation of the urinals and water-closets of each ward is effected by connecting them with the chimneys (70 ft. high) at the end towers, and in which a constant current is maintained by means of the furnace fires used for heating water; the ventilation is farther assisted by tubes connected with these chimneys under which a gas jet is kept burning.

The experience, gained by daily observations continued over rather more than one year, on the subject of the practical working of the aspiratory system, goes to show that the movements of air currents are exceedingly diverse, and that the conditions presented at one time, and those at another, give widely different results.

A high barometer, and a low relative humidity, with either high or low temperature, seem to be the first essential, for a satisfactory, unassisted aspiration; as the relative humidity increases, the aspiration flags, and, on days with the barometer below its normal average, and great humidity, it becomes necessary to employ assistance to the aspiration.

The direction and force of the winds have shown themselves to be important factors in the matter. Aspiration in this building is always satisfactory with the wind from the points, S. W., W., N. W., N., and N. E.; as regards the remaining points of the compass, the reverse is generally true; this may perhaps be explained by the fact that the first named winds are almost always dry, and the last more or less humid; exceptionally we have good aspiration with an east wind but it will then be found that the chimney is kept dry by means of the several fires.

On very quiet days with ordinarily high barometer, low humidity and high or low temperature, aspiration unassisted continues good, while quiet days with reversed conditions give reversed results. From these observations, drawn from practice, it would appear, that dryness, is also an essential factor.

One of the aspirating chimneys of this building receives into its central flue the products of combustion of a furnace used for the heating of water, the same flue is also connected with the kitchen range; one or both these flues are in constant use, summer and winter, night and day; consequently the chimney is kept quite or nearly dry, and its aspirating power is rarely at fault. The other chimney is not directly connected with any constant source of heat, particularly during the Summer season, but is connected with the engine furnace, and boiler—all the waste steam from this source escapes by means of this flue, and in the absence of heat tends to condense upon the interior of the chimney, and renders it moist; as a consequence of this, and a lack of direct heat, especially in the Summer season, the aspiration is frequently imperfect and requires the use of a fire in the grate at the foot of the flue already mentioned.

With the central flues well warmed by heat from any source, ensuring dryness, we have never experienced any difficulty in securing a good upward draught and satisfactory aspiration.

Under the conditions of unassisted aspiration the upward movement of air in the chimneys, as determined by the anemometer, has ranged from a barely perceptible current to 387 feet per minute, the latter being the highest recorded velocity, and deduced from the mean of these observations made at three points of elevation. With brisk fires burning at the bases of the chimneys, and an average temperature within the same of 82° F., the highest recorded observation is 700 feet per minute. I consider a mean velocity of 180 feet per minute, to be nearly a

correct average for long periods, under the usual varying conditions, and including both natural and assisted aspiration. A volume of air, equal in amount to the cubic contents of the chimney, viz: 1927 cubic feet, is displaced about twice a minute from each chimney, equal to about 231,240 cubic feet per hour, the amount of air thus displaced being supplied from sources which will furnish it with the least resistance, and these sources are the wards which freely communicate with each chimney, and the basement of the building.

As before stated, each ward is provided with five foul air outlets, having a practical area of 1.33 square feet each, and five with a practical area of 1.5 square feet each, giving for the four wards a practical area of outlet of 56.60 square feet. The range of a very large number of observations upon the outflow of foul air through these outlets, under varying conditions of aspiration, gives as a result, a velocity of current varying from 20 feet to 600 feet, per minute, for each outlet; those of the lower wards, and lower tier having a slightly greater rate of velocity then the upper ones, and the difference between the velocity of the one nearest the chimney, and the one most remote being little less then $\frac{1}{4}$. As a mean of these extremes, I assume 200 feet per outlet, per minute, to be nearly a correct average. In practice, but one set of ventilating outlets are usually kept open in each ward, and under these circumstances, each chimney will remove about 138,000 cubic feet per hour, from the two wards connected with it.

Fresh, cool or heated air is introduced into the wards by the inlets already described as terminating the ducts having their origin in the main fresh air duct. Under the usual varying conditions peculiar to the movements of bodies of air, the rate of velocity of the current passing through the throat of the main duct ranges from 50 feet to 800 or 900 feet per minute. It has been found in practice that an average inflow of 600 feet per minute, gives the most satisfactory results, and it is the endeavor to

maintain about this velocity by the natural movement of air, if possible, or if this fails, by mechanical means, as by the fan or assisted aspiration.

The average rate of air movement into the inlets of the wards is about 130 feet per minute for each inlet.

The four wards have an aggregate of 48 inlets, with a practical area of 48 square feet; of these 48 inlets, 32 are constantly open for the admission of air; making due allowance for friction not less than 250,000 cubic feet of fresh air are passed into these four wards, per hour, or about 5200 cubic feet per man, per hour. In addition to these four wards all the rooms of the administration building and two large rooms or wards above the pavilion, not connected with the general plan of ventilation, receive their fresh air from the same source.

With the machinery on hand it is possible to increase or diminish this supply, but practically a velocity at the inlets of from 90 to 130 feet per minute is found to give satisfaction. With this velocity the air passes into the rooms well broken up by its passage through the ornamental gratings of the registers and is diffused without draught.

The friction of the air through the main ducts, lateral and distributing flues, is not one-fourth, and with a greater velocity than before indicated the pressure on the air in the more remote and diminished portion of the duct increases the inflow through the registers above. It is often necessary to close more or less accurately the valve doors at the throat, to regulate the inflow, and even sufficient air for a full supply forces its way in through crevices and cracks. When assisted aspiration becomes necessary by means of fires in the grates at the bases of the chimneys, the consumption of fuel has been found to be at the rate of 30 lbs. anthracite coal per hour, per grate. It has rarely been necessary to continue the use of these fires for a longer period than a few hours at a time, but if it should be found desirable to keep them in continuous use, a much less consumption of fuel could be attained by a change of form of

the grate and the provision of dampers to regulate the draught.

III. Ventilation by Propulsion.

Propulsory ventilation is effected by means of a fan placed in a separate building, 74 feet to the west of the hospital and at the point of juncture of the vertical air shaft, and the main fresh air duct, both of which have been previously described.

The fan is an iron disk, 8 feet in diameter, provided with buckets or blades 24 in number, placed at right angles to the disk, each blade or bucket slightly curved to more easily throw off the air, and having a width of 12 inches. The motive power is furnished by a 6 horse power engine placed in the same building. The fan when in motion is cut off from all access of external air, except that which passes down the air shaft, by closely fitting doors.

The smoke, gas and waste steam from the engine are discharged by an underground flue into the central flue passing up the Western aspirating chimney—all water from the boilers, exhaust steam, and all impurities from the engine rooms pass away into a sewer provided for the purpose. The boilers and furnaces are separated from the air duct by two close doors, rendering it impossible for any smoke or coal dust to enter the general circulation.

The fuel used for the engine is Cumberland (soft) coal, and so far as it has been possible to determine, the engine can be run effectively and continuously, night and day, with a consumption of about 140 lbs. per diem. At this Hospital we have made no continuous use of the fan, using it : Summer during the warm stagnant mornings and evenings, to create a draught throughout the building, and during the cooler weather to "blow out" the building, and to assist in the ventilation of the wards. It is also used to regulate the temperature of the wards, as by

its means we can speedily cool off overheated rooms, or in dull, damp and cool weather it is usefully employed, forcing warm air through the building.

The quantity of air supplied by means of the fan varies with its velocity. For experimental purposes, it has been run at all possible rates, and with varying amounts of steam and coal. As an example of what may be done, I give two instances of experimental use.

June 7th, 1877, Temperature of air (external) 75° F. Five o'clock P. M., Temperature of air duct 68° F., 20 lbs. steam, 120 Revolutions of fan per minute.

Anemometer recorded at throat of duct ....1350 feet velocity per minute.
" " under centre of building.. 900 " "

At nearest inlet into ward,

1st story,	(100 feet from throat)	450	feet velocity per minute.
2d "	(118 " ")	420	" "
3d "	(132 " ")	340	" "

At most remote inlet into ward,

1st story,	(298 feet from throat)	410	feet velocity per minute.
2d "	(315 " ")	220	" "
3d "	(331 " ")	199	" "

On this trial all registers were open, also all doors, windows and ventilating outlets.

The second experiment was performed November 1st, 1877.

Temperature of external air 45° F , of duct 46° F., 20 lbs. steam, 120 Revolutions of fan per minute.

Anemometer recorded at throat of duct........................1320 feet per minute.
" " under centre building...................1145 " "

At nearest inlet to ward,

1st story,	(same distances as before)	530	feet per minute.
2d "	(" " ")	360	" "
3d "	(" " ")	269	" "

At most remote inlet to ward,

1st story,	(same distances as before)	750	feet per minute.
2d "	(" " ")	500	" "
3d "	(" " ")	298	" "

In this experiment, all windows and doors were closed, the usual ventilating registers and outlets were open. It

will be observed that the force of the air current at the most remote inlets, exceeds that of the current at the inlet nearest the fan. This fact has been repeatedly observed under similar conditions, and it seems capable of explanation in this way, that the current being driven through a duct constantly and largely diminishing in size, with a greater velocity than it can escape above, it becomes, therefore, compressed in volume and the extra force of the compressed air is added to the original driving force.

A long series of experiments at different seasons of the year have all yielded harmonious results. Beyond a velocity of from 800 to 900 feet per minute in the main duct, the effective force of the air is much impaired, and the result usually seen at the inlets nearest the fan, is a lessened current: the fan under these circumstances fails to throw off the air readily, or to use a technical phrase the fan "churns the air." Our general rule in working the fan is to use 15 lbs. of steam, and not over 60 revolutions per minute, equal to 4-600 ft. per minute in duct; this gives all the air which can possibly be used in the building, and brings down the consumption of fuel to its lowest point. With this velocity, air enters the wards at the rate of from 2 to 4 feet per second, causes no unpleasant draughts, and does not cool down the apartments to an uncomfortable degree. For the purpose of "blowing out" the building, a higher rate of speed is required. As many windows and doors as possible are opened, the air then rushes into the room and is distinctly felt at a distance of 12 feet or more from the register, the general form of the air current being a greatly curved cone which soon becomes broken by contact with similar cones from other inlets, and the body of air in the room is thrown into motion producing fantastic curves and eddies, while an anemometer placed at the foul air outlets or at the windows shows a high velocity, due to the air rushing out. An overheated ward may thus be perfectly aerated in a few minutes.

The use of the fan in connection with this hospital cannot be considered otherwise than a success. Taking into consideration its efficacy in moving and changing air, the comfort to patients both in summer and winter, it is certainly a cheap luxury.

IV. Combination of the Several Systems of Ventilation.

From what has already been said in the preceding pages, it will readily be seen that one system blends almost imperceptibly into another. The three methods may be put in operation at the same time—a very common combination is that of propulsion with aspiration, and the end attained by such combination is still better ventilation than attained by either alone.

General Practical Results Attained by the Methods of Ventilation.

1. For more than a year the ventilation of this hospital has been closely watched and the attendants and employees have been regularly instructed as to their duties in regard to the subject. Almost daily observations in some form have been made upon the practical working, and the best methods of regulating the machinery with a view to the attainment of the end have been carefully studied. It is my belief that a very close approach has been made to perfect success. I have made a point of entering the wards at unexpected hours, and the same liberty has been extended to others who were interested in the subject. I have rarely failed to find a satisfactory condition of the air and that too when the wards have been filled with patients suffering from the worst forms of disease. Whenever an objectionable condition has existed, it has been found without exception, to have been the result of carelessness or negligence of those in whose hands the responsibility was placed.

Simple and natural as are the laws upon which the supply of fresh and the discharge of foul air, are based, and little complicated as is the apparatus, intelligent oversight cannot be dispensed with.

The supposed personal comfort of the patients themselves, is an obstacle in the way of maintaining a proper state of air. Frequently I have found outlets closed which should remain open, and am told that too much heat or too much cold came from registers whose only office was to remove foul air from the rooms.

Fortunately, the general regulation of the apparatus is placed beyond the power of meddlesome interference, and a few general directions to the person in charge are sufficient to maintain great purity of air throughout the building for long periods.

I cannot help again expressing my satisfaction with the fan; by its means, I hold the power of, as it were, deluging the house with fresh air at any moment, and I am convinced that were the provision for the discharge of foul air far inferior to what it is, the use of the fan for a few minutes hourly would maintain a very satisfactory condition of ventilation.

(Signed) D. L. HUNTINGTON,

Surgeon, U. S. A.

II. Experimental Determinations of Carbonic Acid Gas, and Organic Impurities found in the Air of the Wards.

WAR DEPARTMENT,
Surgeon General's Office,
Washington, D. C., November 29, 1877.

Doctor D. L. Huntington,
Surgeon U. S. Army.

Dear Sir:

I forward herewith a tabular statement of the results obtained by me on the night of the 28th inst., in the analysis for Carbonic Acid of the air in certain wards of Barnes Hospital, Soldiers' Home, D. C.

The method which I adopted was the well known and almost universally used one devised by Pettenkoeffer. Every precaution was taken to avoid error in the course of the work by careful re-crystallization of the chemicals used; the protection of the Baryta solution from all possible contact with the air during transport from the Laboratory to your Post (by carrying the measured solution in sealed tubes,) and by protecting the Baryta in the burette, during titration, from contamination by Carbonic Acid, by causing the inflowing air to pass through a Baryta solution contained in a bulbed U tube. Instead of using litmus solution, or turmeric paper as an indicator, I used a strong aqueous extract of Brazil Wood, which I consider decidedly preferable. I may add that I used 75 cubic centimetres of Baryta solution in each experiment, and the results of the first titrations were verified by repetition. I may further add, that the hygrometer used on

the occasion was that of Babinet, which I regard as decidedly the best in use.

The outside air was taken at a point most favorable to insure its freedom from contamination from any source—namely, a point adjacent to the S. E. corner of the building—the wind being at the time South by West, and blowing with a force of about Q. The night was clear and star-light, and every way favorable for the observations.

The first experiment within the building was made in Ward "B," which contained at the time eleven bed patients. The ordinary ventilation was going on at the time, and this Ward was selected as being fairly typical of the conditions which usually obtain in all the wards.

The next experiment was conducted in Ward "D," it contained 12 men, who had been in bed 35 minutes, during which time all the outlets had been closed, while the inlets were left open. That there had been a very considerable accumulation of Carbonic Acid during this time was made evident a minute or two after the introduction of the Baryta solution into the air-bottle, the condition of which presented a marked contrast with that in the bottles used in the previous experiments. The high percentage of Carbonic Acid obtained in this experiment was, therefore, not altogether unexpected, though it is sufficiently in excess of what I had expected from the indications given by the sense of smell on entering the ward, to warrant me in suggesting a repetition of the experiment.

The next, and perhaps the most interesting, experiment of the series was made in the same ward, exactly ten minutes later, during which time all the outlets and inlets were open, the fan running and making 60 revolutions per minute. The low percentage found in this experiment renders needless any remarks on the power of the ventilating machinery for freeing the atmosphere of the wards from all impurity.

AIR. WHENCE TAKEN.	TEMPERATURE.		DIFFERENCE.	RELATIVE HUMIDITY.	BAROMETER.	VOLS. OF CO_2 in 10,000
	DRY BULB.	WET BULB.				
Outside.............	49° Fah.	45° Fah.	4	73	29.72	3.05
Ward "B."........	66° "	57° "	11	49	29.72	6.35
Ward "D." 1st Exper.	77° "	61° "	16	38	29.72	11.23
Ward "D." 2nd "	80° "	66° "	14	41	29.72	3.75

Very respectfully,

Your obedient servant,

(Signed) W. M. MEW,

A. A. Surgeon, U. S. A.

General conditions prevailing at time of observation:

Nov. 28, 1877, 7 to 9 P. M., Wind S. W., nearly calm. Barom. 29-72, Ext. temp. 49°, Rel. Humid. 73°.

Velocity of upward current in East chimney, 130 feet per minute.

Velocity of upward current in West chimney, 110 feet per minute.

Velocity of outflow from foul air register, East Wing, 150 feet per minute.

Velocity of outflow from foul air register, West Wing, 100 feet per minute.

Temperature of both chimneys, 79° F.

RECORD OF OBSERVATIONS

ON

VENTILATION OF THE BARNES HOSPITAL,

AT

WASHINGTON, D. C.

DURING THE YEAR 1876.

The record for each day is the mean of four observations at different hours.

OBSERVATIONS.

Date.	Barometer.	Ex. Temp.	Direction and force of Wind.	East'n Chimney.		Western Chimney.		Outflow from Ward, foul air outlets.—E. Wing.	Outflow from Ward, foul air outlets.—W. Wing.	Remarks.
				Temp. of Chimney.	Velocity of Current.	Temp. of Chimney.	Velocity of Current.			
1876.		Degree		Degree		Degree		Average.	Average.	
July 24.		74.	5 W.–S. W.	75.	275	72.5	225	135	112	Usual fires in E. Wing, no fires in W. Wing. Clear, with fair breeze, dry, all doors and windows open.
July 25.		73.	1 S.–S. W.	75.	190	73.	145	104	97	Usual fires. Currents irregular, air moist and very quiet.
July 26.		75.5	2 S. W.	74.5	180	74.	125	45	Very Irregular.	Usual fire. Current very irregular, cloudy and humid.
July 27.		77.	3 S. E.	74.5	198	75.	148	Irreg	ular.	Usual fires. Aspiration feeble, cloudy and humid, all windows and doors open.
July 28.		79.5	6 S	77.5	240	76.	130	Irreg 122	ular. 85	Usual fires. Aspiration irregular, cloudy with showers during the day. Building more or less open.
July 29.		81.5	5 S.–S. W.	78.	168	77.5	260	172	170	Usual fires in E. Wing. Engine and fan run 4 hours from 8 A. M. to 12 M. Cloudy, with showers.

July 30.		74.5	3 N. E.	73.	75	72	Very Irregular. 50	Very	Irregular.	Rained hard nearly all day. Building quite open, usual fires in E. Wing.
July 31.		72.5	0–4 to W. N. E.–S. E.	72.	200	87.	5–700	135	168–472	Cloudy, with some rain, clearing at 5 P. M. Usual fires in E. Wing. Fire built in grate of W. Chimney and kept up 5 hours. Building open.
Aug. 1.		75.	4 N. W.	75.	276	74.	256	174	135	Clear, dry. Usual fires in E. Wing.
Aug. 2.		77.	0–2 W.–S. W.	76.	140	74.5	85–112	Irregular	and Feeble.	Clear and quiet. Building entirely open.
Aug. 14.	29.78	77.	2 S. E.	75.5	113	75.	80–105	75	40	Cloudy and still. Rel. Humidity 76°. Usual fires in E. Wing. House open.
Aug. 15.	29.72	77.5	2 S. E.	79.	Irregular and Feeble.	77.5	Very Feeble 40	Irreg	ular.	Cloudy and foggy, with very quiet air. Clearer afternoon. Usual fires in E. Wing. Building open. Rel. Humidity 88°.
Aug. 16.	29.81	79.	3 W	80.5	77	78.	Irregular.	Very	Feeble.	Clear and calm. Building entirely open. Rel. Humidity 73°.
Aug. 17.	29.85	82.	2–3 S. W.	79.5	63	79.5	40–70	Irreg	ular.	Clear, with little air. Building open. Rel. Humidity 84°.
Aug. 18.	29.78	76.	3 E.	79.5	145	79.	65	80	Irregular.	Cloudy and quiet. Building partly closed. Rel. Humidity 85°.
Aug. 19.	29.65	77.	1–6 E.–N.	77.	160	77.	195	120	115	Cloudy, with some rain, clearing at 5 P. M. Building partly closed. Rel. Humidity 90°.

OBSERVATIONS—*Continued.*

Date.	Barometer.	Ex. Temp.	Direction and force of Wind.	East'n Chimney.		Western Chimney.		Outflow from Ward, foul air outlets.—E. Wing.	Outflow from Ward, foul air outlets.—W. Wing.	Remarks.
				Temp. of Chimney.	Velocity of Current.	Temp. of Chimney	Velocity of Current.			
		Degree		Degree		Degree		Average.	Average.	
Aug. 20.	29.72	76.	4–6 W	77.	250	76 5	145	170	85–136	Fair, with good breeze. Building open. Rel. Humidity 65°.
Aug. 21.	30.00	64.	4–7 N. W.	71.5	320	70.	301	195	172	Clear and cool, fine breeze. Building partially closed. Rel. Humidity 51.5°.
Aug. 22.	29.94	70.	1–3 W.–S. W.	72.5	280	72.	212	135	127	Clear and pleasant. Building partially closed. Rel. Humidity 62°.
Aug. 23.	29.90	73.5	0 S	74.	115	75.	216	70	187	Rainy, calm. Engine and fan running 6 hours to-day. Building partially closed. Rel. Humidity 72°.
Aug. 24.	29.93	75.	0 S	75.5	52	75.	0–275	Irregular.	0–138	Fair and calm. Building open. Fan run 3 hours. Rel. Humidity 73°.
Aug. 25.	29.88	75.5	1–6 S. E.–W.	77.5	85–154	75.5	45–125	20–98	20–77	Cloudy, clearing at 5 P. M. Building partially closed. Rel. Humidity 76°.
Aug. 26.	29.87	77.	4 N.–N. W.	78.5	295	76.	285	168	152	Clear, becoming calm in after part of day. Building open. Rel. Humidity 66.5°.

Aug. 27.	29.95	67.	5 N. W.	74.	305	73.5	290	236	211	Clear, cool, good breeze. Building partially closed. Rel. Humidity 53.5°.
Aug 28.	29.99	68.	1–2 W.	73.	142	74.	105	115	92	Clear and quiet. Building open. Rel. Humidity 59°.
Aug. 29.	29.94	75.	1–2 S. E.	77.5	115	89.	110–700	87	45–522	Clear, calm. Fire built in grate of W. Chimney, continued 4 hours. Rel. Humidity 65.5°.
Aug. 30.	29.85	77.	2–4 S. E.	77.5	249	76.5	156	147	102	Fair. Building opened. Rel Humidity 61°.
Aug. 31.	29.87	78.	1–3 S. E.	78.	187	77.	86	74	Irregular. 30	Fair and at times perfectly calm. Building fully open. Rel. Humidity 57°.
Sept. 1.	29.75	80.	1 S. E.	80.	187	78.	97	68	Irregular. 30	Cloudy and clear, calm. Building open. Rel. Humidity 71.5°.
Sept. 2.	29.80	77.	1–5 N. W.	79.	267	76.	184	189	123	Clear. Building open. Rel. Humidity 42.5°.
Sept. 3.	29.97	72.	2–3 N. W.	73.5	302	73.5	274	190	172	Clear, cool, fine breeze. Building partially open. Rel. Humidity 54°.
Sept. 4.	29.92	72.	2–3 S. W.	74.5	316	72.5	220	175	157	Clear, cool, pleasant. Building partially closed. Rel. Humidity 53.6°.
Sept. 5.	29.93	70.	2 N. W.	73.	322	71.	290	177	165	Clear, cool, pleasant. Building partially closed. Rel. Humidity 53°.
Sept. 6.	30.01	65.	3 E.–S. E.	71.	93–212	67.	276	0–79	0–170	Cloudy, with rain. Building partially closed. Fan running 6 hours. Rel. Humidity 74°.

OBSERVATIONS—*Continued.*

Date.	Barometer.	Ex. Temp.	Direction and force of Wind.	East'n Chimney		Western Chimney.		Outflow from Ward, foul air outlets.—E. Wing.	Outflow from Ward, foul air outlets.—W. Wing.	Remarks.
				Temp. of Chimney.	Velocity of Current.	Temp. of Chimney.	Velocity of Current.			
Sept. 7.	29.81	Degree 69.	1–3 S. E.	Degree 74.	80–200	Degree 69.	0–210	Average. 0–120	Average. 0–170	Cloudy, partially clearing. Building closed. Fan running 4 hours. Rel. Humidity 81°.
Sept. 8.	29.74	74.	2–3 S. E.	74.	122–211	73.	0–118	137	0–67	Partially cloudy. Building closed. Rel. Humidity 77°.
Sept. 9.	29.87	71.	2–3 N. W.	76.5	300	74.	315	195	240	Clear and cool. Building partially closed. Fan running 8 hours. Rel. Humidity 57°.
Sept. 10.	29.92	68.	2–4 N.E.–N.	73.	240	69.	250	200	200	Rainy. House closed. Fires in grates. Av. temp. of House 70°. Rel. Humidity 79°.
Sept. 11.	29.68	66.	4 N. E.	71.	100–220	71.	Irregular. 100	60	Irregular. 50	Cloudy, with light rain. House closed. Grate fires. Rel. Humidity 85°.
Sept. 12.	29.75	65.	3 S. E.	70.	127–220	67.	Very Irregular.	60–120 Very	Irregular.	Cloudy. House closed. Fires in grates. Temp. int. 71°. Rel. Humidity 87°.

Sept. 13.	29.91	65.	1–3 S.E.–S.W.	70.	195	67.	270	100	167	Cloudy. House closed. Fan running 4 hours. Rel. Humidity 79°.
Sept. 14	29.94	67.	3–4 S. W.	73.	247	68.	207	168	137	Cloudy, clearing during the day. House partially closed. Rel. Humidity 73°.
Sept. 15.	29.88	71.	3 S. W.	73.	262	71.	213	157	145	Fair. House partially open. Rel Humidity 67°.
Sept. 16.	30.01	65.	4 N. E.	73.	179	69.	0–150	120	Irregular.	Cloudy, light rain. House closed. Fire in grates. Rel. Humidity 84°.
Sept. 17.	29.72	66.	4–6 E.–S. W.	70.	Very Irregular 0–200	66.	Very Irregular. 0–225	Very 0–175	Irregular. 0–130	Hard rain with high wind. House closed. Grate Fires. Rel. Humidity 93°.
Sept. 18.	29.[illegible]1	68.	4–6 S. W.	70.5	476	67.5	212	287	190	Fair, high wind. House closed. Grate fires. Rel. Humidity 66°.
Sept. 19.	29.70	67.	5 N. W.	71.5	254	68.5	321	190	202	Fair, high wind. House closed. Grate fires. Rel. Humidity 65°.
Sept. 20	29.80	66.5	2–3 N.W.–N.E.	71.	256	69.	240	187	116	Fair, light clouds. House closed. Rel. Humidity 72°.
Sept. 21.	29.94	67.5	3–4 N. E.–E.	71.5	191	68.	290	75–144	162	Cloudy. House closed. Rel. Humidity 79°.
Sept. 22.	29.99	63.5	4 S. E.	68.	282	65.	231	142	127	Raining hard. House closed. Grate fires. Temp. of House 70°. Rel. Humidity 90°.

OBSERVATIONS—*Continued.*

Date.	Barometer.	Ex. Temp.	Direction and force of Wind.	East'n Chimney. Temp. of Chimney.	East'n Chimney. Velocity of Current.	Western Chimney. Temp. of Chimney.	Western Chimney. Velocity of Current.	Outflow from Ward, foul air outlets.—E. Wing.	Outflow from Ward, foul air outlets.—W. Wing.	Remarks.
		Degree		Degree		Degree		Average.	Average.	
Sept. 23.	29.75	67.2	2 S. E.	80.	414	68.	100	292	10–77	Raining hard. Moderate fire in grate of Eastern Chimney continued 6 hours. Rel. Humidity 95°.
Sept. 24.	29.68	65.	2–5 N. E.	70.	320	69.	225	188	140	Rainy and cloudy. Grate fires. Temp. of House 71°. Rel. Humidity 90°.
Sept. 25.	29.82	65.5	1–4 N. W.	72.	336	68.	204	172	90–125	Clearing Weather. Fire in grates continued. House temp. 72°. Rel Humidity 80°.
Sept. 26.	29.60	60.	2–6 S.W–N.W.	70.5	362	65.	215	211	172	Clear, with wind. Fires. House temp. 70°. Rel. Humidity 70°.
Sept. 27.	29.90	54.	4–6 N. W.	67.	386	67.	584	269	127–312	Clear, with wind. Grates fires. Fan running 6½ hours. Temp. of House 68°–73°. Rel. Humidity 53°.
Sept. 28.	30.02	57.	2–5 N. W.	64.	325	61.5	300	187	194	Clear, with wind. Fires in grates. Temp. of House 70°. Rel Humidity 57°.

Sept. 29.	....	....	....	....	....	....	....	....	....	No observations taken on these 2 dates.
Sept. 30.	....	....	....	....	....	....	....	....	....	
Oct. 1.	29.82	52.	2–4 N. W.	55.	362	74.	425	202	300	Clear, cloudy later. Fire started to-day in Western Furnace. Temp. of House 70°–74°. Rel. Humidity 68°.
Oct. 2.	29.83	47.	3 W.–N. W.	60.	315	76.	460	187	340	Fair. Same condition as above. Gen. temp. of House 70°–73°. Av. velocity of inflow of warm air 147 feet per minute. Rel. Humidity 64°.
Oct. 3.	29.80	51.5	2–3 W.–S.	62.	298	76.5	400	130	220	Partly clear. Gen. temp. of House 70°–75°. Main air duct wide open. Av. vel. of inflow throughout House 220 feet per minute. Rel. Humidity 72°.
Oct. 4.	29.73	54.5	1–2 W.S.–W.N	59.	170	76.	352	90–115	177	Cloudy, calm. Gen. House temp. 70°. Av. inflow vel. 170 feet per minute. Rel. Humidity 73°.
Oct. 5.	29.81	52.	3–5 N. E.–N.	60.	182	77.5	380	70–90	147	Cloudy, damp wind. Gen. House temp. 72°. Av. inflow warm air 254 feet per minute. Rel Humidity 82°.
Oct. 6.	29.58	53.	4–7 S.E.–S.W.	59.	Irregular	74.	522	Irregular.	260	Cloudy, with damp and fog. House temp. 73°. Av. inflow warm air 324 feet per minute. Rel. Humidity 80°.
Oct. 7.	29.73	50.	2–6 W.–N. W.	56.	315	77.	511	240	292	Clear and cool, high wind. House temp. 70°. Av. inflow of war ı air 390 feet. Rel. Humidity 52°.

OBSERVATIONS—*Continued.*

Date.	Barometer.	Ex. Temp.	Direction and force of Wind.	East'n Chimney. Temp. of Chimney.	East'n Chimney. Velocity of Current.	Western Chimney. Temp. of Chimney.	Western Chimney. Velocity of Current.	Outflow from Ward, foul air outlets.—E. Wing.	Outflow from Ward, foul air outlets — W. Wing.	Remarks.
		Degree.		Degree		Degree		Average.	Average.	
Oct. 8.	29.97	47.	2–5 W.–N.	52.	327	77.	492	188	192	Fair, with clouds in the afternoon. House temp. 70°–74°. Av. inflow 210 feet. Main air duct closed. Rel. Humidity 62°.
Oct. 9.	30.13	46.5	1–3 N.–S.	55.	200	75.	372	60–110	145	Fair and calm. House temp. 73°. Av. inflow 146 feet per minute. Main air duct open. Rel. Humidity 63°.
Oct. 10.	29.72	55.	2–5 S.W.–S.	61.	140	72.	315	50–90	161	Cloudy and warmer. Fire in furnace slackened. Temp. of House 69°. Inflow 130 feet per minute. Rel. Humidity 73°.
Oct. 11.	29.91	44.5	4–6 N. W.	50.	300	76.	480	174	280	Clear and cool. House temp. 73°. Av. inflow 350 feet per minute. Rel. Humidity 48°.
Oct. 12.	30.26	42.5	1–2 N.–S.	51.	125	75.	306	60–100	180	Clear and calm. House temp. 70°–74°. Av. inflow 182 feet. Rel. Humidity 63°.

Oct. 13.	30.03	50.	2–3 S. W.–S.	56.	140	77.	320	80–120	165	Smoky and calm. House temp. 70°–76°. Inflow irregular. Rel. Humidity 70°.
Oct. 14.	29.75	58.	4–5 S.	60.	115	77.	225	Irregular.	100	Smoky, with calms and breezes. House temp. 74°. Inflow 145 feet. Fires banked. Rel. Humidity 76°.
Dec. 3.	30.01	32.	2–6 N. W.	78.	427	76.	480	270	289	Clear and cool. Both furnaces operating. Temp. of House 75°. Av. inflow of warm air 220 feet per minute. Rel. Humidity 68°.
Dec. 4.	30.11	29.	4–6 N. W.	79.	504	77.	559	290–	420	Smoky, cool. Temp. of House 76°. Av. inflow of warm air 272 feet. Rel. Humidity 66°.
Dec. 5.	30.05	29.	4–7 N.	78.	515	78.	532	200–	310	Cloudy, cool. Temp of House 70°–76°. Av. inflow of warm air 300 feet. Rel. Humidity 80°.
Dec. 6.	30 05	32.	1–3 N.–S.	75.5	378	77.	362	150–	248	Smoky, cool. Av. temp. of House 72°. Av. inflow of warm air 185 feet. Rel. Humidity 61°.
Dec. 18.	29.85	21.5	4–7 S.E.–N.W.	81.	395	79.	400	250–	300	Cloudy, snow. Av. temp. of House 74°. Av. inflow of warm air 350 feet. Rel. Humidity 82°.
Dec. 25.	30.11	23.	4–5 N.	80.	400	80.	360	200–	350	Cloudy, snow and sleet. Temp. of House 76°. Av. inflow of warm air 250 feet. Fan running for 2 hours. Rel. Humidity 91°.
Dec. 31.	30.00	21.	4–6 N. W.	81.	575	80.	565	350–	480	Clear, cold. Temp. of House 72°–76°. Av. inflow of warm air 275 feet. Rel. Humidity 60°.

Consolidated Record of fuel consumed at Barnes Hospital, U. S. Soldiers' Home, from October 1st, 1876, to September 30th, 1877.

DATE.	EAST FURNACE.	WEST FURNACE	KITCHEN.	HOT WATER BOILERS	MISCEL-LANEOUS.	TOTAL.	REMARKS.
From Week ending October 8, to Week ending November 26	....	53,848	10,176	8,160	2,883	75,067	Mean average Temperature for Period, 53.6°.
From Week ending December 3, to Week ending January 28	66,992	62,752	12,720	13,490	4,653	16[illegible],607	Mean average Temperature for Period, 28 6°.
From Week ending February 4, to Week ending March 25	54.272	23,744	9,328	11,660	2,150	101,154	Mean average Temperature for Period, 37 6°.
From Week ending April 1, to Week ending May 27	36,888	....	9,964	8,920	750	56,522	Mean average Temperature for Period, 53 3°.
From Week ending June 3, to Week ending July 29	....	....	9,540	6,400	....	15,940	Mean average Temperature for Period, 73.9°.
From Week ending August 5, to Week ending September 30	....	....	8,692	6,140	....	14,832	Mean average Temperature for Period. 68.2°.
Total for year	158,152	140,344	60,420	54,770	10,436	424,122	

REMARKS:—The miscellaneous use noted above has been for grates and for fires in ventilating chimneys.
The price per ton paid for Hard Coal was $6.48 per ton of 2240 pounds. Cumberland Coal $6 00 per ton.
This paper shows the exact expenditure for the purposes indicated by the several headings.

RECORD OF OBSERVATIONS *on Heating and Ventilation of the Barnes Hospital, for month of Dec.*, 1877.

Each Observation is the mean of three trials. All velocities, in feet, per minute.

DATE—1877, DECEMBER.	1	2	3	4	5	6	7	8	9	10	11
Barometer	29.804	30.268	30.230	30.062	29.615	29.771	30 125	29.342	30 244	30.016	29.932
External Temperature	38°	31°	33.5	37	53	40	36 5	40	34	36	48
Wind, direction and force	N. W.^{2}	N^{2}	N. W. S. E. 1	S.^{3}	S. W. 0 – 4	N. W. 4 – 6	S. W. 1 – 4	W. 1 – 4	S.W. W 2 – 4	S W. 4	S W. 2
Relative humidity of External Air	87	92	66	78	78	58	57	45	45	57	57
Aspirating Chimneys, East, Temperature of chimney	69	75	76	75	75	75	75 5	75.5	78	75	76
Aspirating Chimneys, East, Velocity of air current	186	280	375	346	326	400	444	361	242	230	225
Aspirating Chimneys, West, Temperature of chimney	70	73	74	73	74	76	73	71	75	72	76
Aspirating Chimneys, West, Velocity of air current	126	150	280	293	150	353	264	348	235	331	201
Outflow from foul air registers, East wing.	200	150	120	139	120	190	240	186	216	330	243
Outflow from foul air registers, West wing.	210	153	146	113	106	180	213	130	198	286	238
Inflow of fresh air, East wing	150	205	173	190	306	166	189	240	331	195	160
Inflow of fresh air, West wing	110	166	153	166	340	160	220	221	350	153	138

REMARKS:—December 1. Clear and cool. Both furnaces going. Fan not running.
" 2. Calm and cool. Both furnaces going. Fan not running.
" 3. Cloudy and still. Both furnaces going. Fan running moderately.
" 4. Cloudy with rain. Fan running. Both furnaces running.
" 5. Warm and muggy. W. furnace discontinued. Fan not running.

REMARKS:—December 6. Fan not running. W. furnace discontinued.
" 7. Clear and cool. Fan not running. W. furnace discontinued.
" 8. Clear and cool. Fan not running. W. furnace not going.
" 9. Fan not running. W. furnace not going.
" 10. Fan not running. House open. No fire in W. furnace.
" 11. Fan not running. No fire in W. furnace. House open. Air duct fully open.

RECORD OF OBSERVATIONS.—CONTINUED.

DATE —1877, DECEMBER	12	13	14	15	16	1	18	19	20	21
Barometer	30.151	29.759	30.158	30.003	29.994	29.959	30.291	30 198	30.128	30 350
External Temperature	49	49	39	42	54	52	41	45	55	46
Wind, direction and force	N. E. S. W. 1	S. W. N. W. 3	N. W. 1	S. W. 2	S. S. W. 1	W. S. W. 1 – 2	S. W. N. E. 1	S. E. 1 – 3	S. W. N. W. 1	N. E. 1
Relative humidity of external air	66	64	48	53	63	79	71	74	71	74
Aspirating Chimneys, East. Temperature of chimney	77	76	70	71	77	81	79	76	77	79
Aspirating Chimneys, East. Velocity of air current	230	258	216	283	272	160	246	360	363	460
Aspirating Chimneys, West. Temperature of chimney	74	72	69.5	68	71	71	71	70	69	71
Aspirating Chimneys, West. Velocity of air current	171	206	270	256	225	90	2[illegible]3	260	220	280
Outflow from foul air registers, East Wing	167	222	240	273	270	200	163	281	312	363
Outflow from foul air registers, West Wing	186	187	251	225	235	198	135	250	222	310
Inflow of fresh air, East Wing	146	260	241	208	207	244	213	226	380	260
Inflow of fresh air, West Wing	152	254	229	220	223	251	234	202	223	258

REMARKS:—December 12. Same as 11th.
" 13. Fan running at intervals. House open. No fire in W. furnace.
" 14. Same as 13th.
" 15. Same as 14th.
" 16. Fire banked. Fan running at intervals. House open.

REMARKS:—December 17. Warm. Fan running at intervals. Fires banked. House open.
" 18. Same as 17th.
" 19. Fan running all day. Very small fires in furnace. House open.
" 20. Same as 19th.
" 21. Same as 20th.

RECORD OF OBSERVATIONS.—CONTINUED.

DATE —1877, DECEMBER	22	23	24	25	26	27	28	29	30	31
Barometer	30.321	30.307	30.310	29.881	29 740	29.826	29.922	29.758	29.188	29.442
External Temperature	45	46	43	40	43	45	47	42	35	35
Wind, direction and force	N. E. 1	N. E. 1	S. E. 2	S. E. 1	S E. E. 2	N. E. 1 – 2	N. E. 1 – 2	E. N. E. 2 – 5	N. E. 4 – 5	N. 4 – 6
Relative humidity of external air	76	78	92	100	85	78	58	66	90	64
Aspirating Chimneys, East, Temperature of chimney	79	79	79	79	77.5	74	73	75	75	77.5
Aspirating Chimneys, East, Velocity of air current	453	443	530	516	591	300	320	443	430	410
Aspirating Chimneys, West, Temperature of chimney	70	71	71	71	71	71.5	71	69	62	67
Aspirating Chimneys, West, Velocity of air current	306	283	333	315	313	223	260	340	433	546
Outflow from foul air registers, East Wing	410	423	415	335	390	238	280	356	363	410
Outflow from foul air registers, West Wing	370	323	395	336	456	257	226	320	246	366
Inflow of fresh air, East Wing	226	236	390	241	333	396	483	400	223	386
Inflow of fresh air, West Wing	206	326	486	233	360	293	423	438	216	386

REMARKS:—December 22. Same as 21st.
" 23. Cloudy. Fan running.
" 24. Fog with rain. Fan running all day.
" 25. Fog and damp. Fan running all day.
" 26. Cloudy with rain. Fan running all day.

REMARKS:—December 27. Cloudy still. Fan running all day.
" 28. Fan running all day.
" 29. Cloudy with rain. Fan running all day.
" 30. Rain with wind. Fan not running.
" 31. Clear and cool with wind. Fan used at intervals.

RECORD OF OBSERVATIONS.—Continued.

Date—1877, December	1	2	3	4	5	6	7	8	9	10	11
Gauge of Heating Furnaces	135	142	142	140	135	140	143	144	150	142	135
Temperature of hot air at registers of Wards, E. Wing	97	98	102	102	104	103	96	102	87	89	98
" " " " " W. Wing	100	105	106	93	100	108	102	106	88	87	108
Average Temperature of Wards at floor, E. Wing	71	73	74	71	72	71	72	76	72	72	73
" " " " at centre, E. Wing	73	75	74	73	74	75	76	77	74	72	74
" " " " at ceiling, E. Wing	73	76	76	75	75	73	73	80	76	74	76
" " " " at floor, W. Wing	72	70	72	74	74	72	74	74	70	70	72
" " " " at centre, W. Wing	72	72	71	69	72	72	74	74	74	73	74
" " " " at ceiling, W. Wing	74	73	73	70	74	74	77	77	76	73	77
Temperature of distal foul air boxes, E. Wing	72	70	75	73	77	76	73	77	76	71	74
" " " " W. Wing	73	71	74	72	75	72	74	74	75	73	75
Average Relative Humidity of House	59	45	44	54	56	52	47	43	49	49	60

Remarks:—December 1. Clear and cool. Both furnaces going. Fan not running.
" 2. Calm and Cool. Both furnaces going. Fan not running.
" 3. Cloudy and still. Both furnaces going. Fan running moderately.
" 4. Cloudy with rain. Fan running. Both furnaces running.
" 5. Warm and muggy. W. furnace discontinued. Fan not running.
" 6. Fan not running. W. furnace discontinued.
" 7. Clear and cool. Fan not running. W. furnace discontinued.
" 8. Clear and cool. Fan not running. W. furnace not going.
" 9. Fan not running. W. furnace not going.
" 10. Fan not running. House open. No fire in W. furnace.
" 11. Fan not running. No fire in W. furnace. House open. Air duct fully open.

RECORD OF OBSERVATIONS.—CONTINUED.

DATE—1877, DECEMBER	12	13	14	15	16	17	18	19	20	21
Gauge of Heating Furnaces	128	113	119	115	113	114	121	114	106	126
Temperature of hot air at registers of Wards, E. Wing	94	92	91	86	82	87	87	86	85	95
" " " " " W. Wing	93	86	82	88	87	89	89	87	86	94
Average Temperature of Wards at floor, E. Wing	70	69	68	68	67	69	68	67	65	66
" " " " at centre, E. Wing	72	71	69	70	69	71	70	69	66	69
" " " " at ceiling, E. Wing	75	74	71	72	72	72	72	71	66	72
" " " " at floor, W. Wing	74	71	69	66	70	69	71	66	66	70
" " " " at centre, W. Wing	75	72	69	68	71	70	73	72	68	71
" " " " at ceiling, W. Wing	76	74	71	70	73	71	74	72	69	74
Temperature of distal foul air boxes, E. Wing	72	70	71	71	72	72	71	71	64	72
" " " " W. Wing	75	72	70	70	72	70	71	70	69	72
Average Relative Humidity of House	57	57	55	56	53	57	56	63	59	56

REMARKS:—December 12. Same as 11th.
" 13. Fan running at intervals. House open. No fire in W. furnace.
" 14. Same as 13th.
" 15. Same as 14th.
" 16. Fire banked. Fan running at intervals. House open.
" 17. Warm. Fan running at intervals. Fires banked. House open.
" 18. Same as 17th.
" 19. Fan running all day. Very small fires in furnace. House open.
" 20. Same as 19th.
" 21. Same as 20th.

RECORD OF OBSERVATIONS.—Continued.

Date—1877, December	22	23	24	25	26	27	28	29	30	31
Gauge of Heating Furnaces	122	114	116	116	123	116	116	123	134	140
Temperature of hot air at registers of Wards, E. Wing	88	89	92	93	92	91	88	90	97	93
" " " " " W. Wing	92	89	90	98	93	82	87	85	95	90
Average Temperature of Wards at floor, E. Wing	68	70	68	69	68	67	67	66	68	69
" " " " at centre, E. Wing	70	71	70	72	69	67	69	69	70	71
" " " " at ceiling E. Wing	73	72	74	74	70	71	71	72	72	73
" " " " at floor, W. Wing	69	71	70	71	69	68	69	66	68	68
" " " " at centre, W. Wing	71	73	70	72	72	68	70	69	70	72
" " " " at ceiling, W. Wing	73	73	73	74	73	71	71	71	72	73
Temperature of distal foul air boxes, E. Wing	73	70	73	72	71	70	70	68	70	69
" " " " W. Wing	70	72	73	72	72	70	69	68	72	71
Average Relative Humidity of House	62	56	60	64	61	60	56	59	62	60

Remarks:—December 22. Same as 21st.
" 23. Cloudy. Fan running.
" 24. Fog with rain. Fan running all day.
" 25. Fog and damp. Fan running all day.
" 26. Cloudy with rain. Fan running all day.
" 27. Cloudy still. Fan running all day.
" 28. Fan running all day.
" 29. Cloudy with rain. Fan running all day.
" 30. Fan not running. Rain with wind.
" 31. Clear and cool, with wind. Fan used at intervals.

Remarks to accompany Table of Observations.

The preceding table gives the average results of three daily observations, taken at 7 A. M., 2 P. M. and 9 P. M.

Amount of Anthracite Coal used for Heating purposes only, in the Month of December, 1877.

DATE.	POUNDS.	TEMPERATURE.
December 1st and 2d......	2,368	Mean average of 1st and 2d, 39°.
Week ending Dec. 9th....	11,872	" " Week...... 38°.
" " " 16th....	8,056	" " " ......45°.
" " " 23d.....	6,360	" " " ......47°.
" " " 30th....	7,208	" " " ......43°.
December 31st............	1,225	" " 31st.
	37,089	

Both furnaces in operation from December 1—6, for remainder of month but one.

Comparison may be made with corresponding period of last year, in coal consumption, by reference to tables already forwarded.

Amount of Bituminous (Cumberland) Coal used for Engine purposes only, in December, 1877.

DATE.	POUNDS.	REMARKS.
From 1st to 9th incl......	424	Fan not running 1st and 2d.
" 10th " 16th "	848	During the month the fan has been used 20 days.
" 17th " 23d "	742	
" 24th " 30th "	954	Steam kept up from 6 A. M. to 9 P. M.
December 31st.............	148	
	3,116	Average velocity of fan, 45 revolutions. Steam 15 to 20 lbs.

RECORD FOR MONTH OF JANUARY, 1878.

DATE.—1878, JANUARY	1	2 *	3 *	4	5	6	7	8 *	9 *	10	11
Barometer	29.656	29.693	30.196	29.444	29.998	29.964	30.386	30.380	30.226	29.976	29.548
External Temperature	38	34	29	26	24	27	19	25	26	46	45
Direction and force of Wind	N.W.2	N.W.2	N.W.2	E.N.W 5.6	N. W. 4	N. W. 6	N. W. 3	S. 1	0	0	W. 4
Relative humidity, external	82	65	....	.. ...	....	....	....	....	....	86	85
Aspirating Chimney. East. Temperature	77	77	77	79	80	80	82	77	79	78	80
Aspirating Chimney. East. Velocity	500	386	410	560	360	660	480	460	520	360	200
Aspirating Chimney. West. Temperature	72	74	72	74	73	74	73	73	74	74	70
Aspirating Chimney. West. Velocity	400	320	450	410	530	610	630	440	280	300	480
Outflow from foul air duct, East Wing	330	370	440	320	200	430	280	320	300	280	240
" " " " West "	280	320	480	390	440	601	310	260	240	240	500
Inflow of fresh air, East Wing	260	230	280	190	390	370	320	250	280	300	420
" " West "	280	330	250	180	380	310	240	200	230	140	360

* Fan used.

RECORD—CONTINUED.

DATE.—1878, JANUARY	12	13	14	15	16	17	18	19 *	20	21
Barometer	29.642	29.854	29.476	29.672	30.000	30.010	30.076	30.050	29.770	29.594
External Temperature	46	42	42	44	38	37	48	48	43	43
Direction and force of Wind	W. 1	0	S. W. 2	W. 5	N. W. 3	S. W. 2	E. 3.	0	E. 1	0
Relative humidity, external	74	78	84	59	62	68	57	73	100	100
Aspirating Chimney. East. Temperature	66	74	75	84	77	76	77	80	75	76
Aspirating Chimney. East. Velocity	150	120	360	480	320	328	320	520	260	240
Aspirating Chimney. West. Temperature	69	65	67	70	73	73	71	72	70	70
Aspirating Chimney. West. Velocity	200	130	Irreg'r	360	240	240	160	450	360	290
Outflow from foul air duct, East Wing	260	120	160	360	160	210	240	600	120	160
" " " " West "	200	240	140	280	240	340	320	400	200	280
Inflow of fresh air, East Wing	200	260	270	360	240	280	240	540	250	240
" " West "	240	200	180	320	200	200	130	640	210	200

* Fan used.

RECORD—CONTINUED.

DATE.—1878, JANUARY.	22 *	23	24 *	25 *	26 *	27	28 *	29	30	31 *
Barometer	29.560	30.060	30.200	29.950	29.800	29.874	29.680	30.010	30.226	29.440
External Temperature	52	23	34	48	47	44	40	32	33	33
Direction and force of Wind	W. 2	N. W. 5	S. W. 4	0	S. W. 3	E. 3	N. E. 2	N. E. 4	N. E. 2	E. 6
Relative humidity, external	54	....	....	86	49	78	72	....	....	....
Aspirating Chimney. East. Temperature	73	76	76	73	76	73	76	72	73	73
Aspirating Chimney. East. Velocity	360	410	540	240	400	360	300	420	320	280
Aspirating Chimney. West. Temperature	66	71	75	70	71	70	70	69	69	70
Aspirating Chimney. West. Velocity	200	380	620	200	400	540	600	480	120	520
Outflow from foul air duct, East Wing	240	250	400	240	260	200	240	210	130	160
" " " " West "	200	280	410	260	280	220	260	220	200	140
Inflow of fresh air, East Wing	600	200	360	600	560	200	420	200	180	160
" " West "	600	260	320	580	540	180	380	220	200	180

* Fan used.

RECORD—CONTINUED.

DATE.—1878, JANUARY	1	2	3	4	5	6	7	8	9	10	11
Hot Water furnace Gauge	135	142	145	150	152	155	160	158	160	140	140
Temperature of hot air entering Registers, East Wing.	103	105	111	104	119	108	116	114	116	113	109
" " " " West "	104	100	112	106	104	92	106	110	112	110	98
Temperature of Wards. E. W. Floor	69	66	69	71	68	69	68	66	68	70	74
Temperature of Wards. E. W. Centre.	74	70	73	72	72	76	76	74	75	73	76
Temperature of Wards. E. W. Ceiling	76	74	75	74	74	78	78	75	78	74	77
Temperature of Wards. W. W. Floor	68	70	69	67	65	66	68	66	67	68	73
Temperature of Wards. W. W. Centre.	72	73	72	71	68	72	74	70	71	72	75
Temperature of Wards. W. W. Ceiling	74	75	75	74	71	74	76	75	75	73	76
Temperature of foul air duct, E. W.	73	72	73	74	65	73	72	71	72	75	74
" " " W. W	71	74	72	71	68	72	72	70	71	73	74
Relative humidity internal air	67	60	63	48	52	57	53	56	60	73	56

RECORD—CONTINUED.

DATE.—1878, JANUARY	12	13	14	15	16	17	18	19	20	21
Hot Water furnace Gauge	126	130	128	135	150	145	136	122	126	134
Temperature of hot air entering Registers, E. W.	112	115	113	104	111	116	111	97	102	112
" " " " W. W.	97	107	104	98	107	113	94	90	98	98
Temperature of Wards. E. W. Floor	72	72	73	73	71	70	71	71	74	72
Temperature of Wards. E. W. Centre	74	76	75	75	74	75	74	73	75	74
Temperature of Wards. E. W. Ceiling	76	78	77	76	76	78	76	75	78	76
Temperature of Wards. W. W. Floor	70	70	70	71	72	71	66	68	70	70
Temperature of Wards. W. W. Centre	71	75	74	72	76	78	71	70	72	73
Temperature of Wards. W. W. Ceiling	72	77	76	73	77	79	73	72	73	75
Temperature of foul air duct, E. W.	76	76	78	74	72	74	73	74	76	75
" " " W. W.	73	77	76	73	73	73	70	72	73	73
Relative humidity internal air	56	60	67	60	55	57	60	66	82	73

RECORD—CONTINUED.

DATE.—1878, JANUARY.	22	23	24	25	26	27	28	29	30	31
Hot Water furnace Gauge	110	162	154	128	122	130	128	146	142	144
Temperature of hot air entering Registers, E. W.	90	115	114	103	99	106	108	102	106	118
" " " " W. W.	84	114	115	94	96	99	104	100	104	110
Temperature of Wards. E. W. Floor	68	70	72	71	72	70	72	70	71	69
Temperature of Wards. E. W. Centre	70	71	75	73	73	72	70	72	72	71
Temperature of Wards. E. W. Ceiling	72	72	76	75	74	74	73	74	73	72
Temperature of Wards. W. W. Floor	64	70	69	68	71	67	76	72	66	67
Temperature of Wards. W. W. Centre	68	71	71	70	72	69	69	73	67	68
Temperature of Wards. W. W. Ceiling	72	72	73	72	73	71	71	74	69	69
Temperature of foul air duct, E. W.	72	72	74	75	75	73	72	73	71	70
" " " W. W.	69	72	73	72	76	72	73	73	69	69
Relative humidity internal air	69	60	55	78	60	57	72	57	68	78

Mean Average Temperature of Month,—35.4°

Amount of Anthracite Coal consumed in heating Hospital,—51,684 lbs.

Amount of Bituminous Coal consumed in running Engine,— 2226 lbs.

At my request Dr. Edward Cowles, Superintendent of the Boston City Hospital, has made a series of experiments and observations upon the heating and ventilation of one of the one story wards above referred to and has been kind enough to furnish me with carefully prepared tables of the results obtained. It is almost unnecessary to say that the same reliance may be placed upon Dr. Cowles care and accuracy as upon those of Dr. Huntington, so that their observations are strictly comparable, and I consider it as a special piece of good fortune, that the observations should have been made by these two gentlemen.

The building in which Dr. Cowles' observations were made contains the ward 94 by 26⅓ feet in the clear, which has 7 opposite windows and 14 beds on each side. The windows are double sashed. The height of the ward from the floor to the centre of the arched ceiling is 20 feet, or an average of 18.42 feet. Each bed has a floor area of 88.45 square feet, and an air space of 1629 cubic feet. The total air space of the ward is about 45,600 cubic feet.

Beneath the ward is an open and free air space containing only heating apparatus. The Engineer alone has access to this basement, and the sole charge of the adjustment of the valves. The air enters the wards only through inlets under each window, 14 in all, each inlet equal to 1 square foot of clear opening. The cold air is introduced through openings in the outer basement walls, and passes immediately over the steam coils, of which there is a separate one for every flue.

The steam radiators in the basement are encased with galvanized iron, forming a small chamber in which a switch valve directs the fresh air, so that it passes either through the coil so as to be warmed, or, unwarmed, directly into the flue above. A wire is attached to the switch valve in the room above, where by the use of a key the valve can be adjusted to alter the temperature of the entering air. The volume of air can only be changed by opening or closing a sliding valve covering the inlet through

the basement wall, and this is under the charge of the engineer. The foul air escapes through five large openings along the centre of the arched ceiling, each about 3 feet by 6 feet,—total clear opening 50.9 sq. ft.—into the ridge-chamber, and thence either through the free openings in the sides of the chamber above the roof, or through five ventilators, each 2¼ feet in diameter, on the top of the ridge. The side openings are closed in winter, when also the openings in the floor of the chamber can be partly or wholly closed, and the ventilation aided by the flues, 14 in number, in the outer walls of the building. The ventilating-chamber is warmed when necessary, by steam pipes. For full description of this ward with illustrations, see Med. and Surg. Reports of the Boston City Hospital, 2nd ser., Boston, 1877. The observations made in the ward, cover a period of two weeks, and the results are given in the following tables. They show the amount of air introduced into and removed from the ward, the amount of heat imparted to it and approximately, the amount of coal consumed for this purpose.

RECORD OF OBSERVATIONS

On Heating and Veatilation, made at the Boston City Hospital during the week ending December 25th, 1877.

Day of the Month of December		19	20	21	22	23	24	25
Daily mean of Barometer		30.31	30.33	30.61	30.45	30.49	30.26	30.08
External Temperature	7 A. M.	32.	47.	24.	35.	28.	28.	28.
	2 P. M.	48.	51.	36.	39.	45.	43.	40.
	9 P. M.	46.	36.	32.	37.	34.	36.	34.
Relative Humidity	7 A. M.	69.	77.	74.	61.	77.	77.	77.
	2 P. M.	49.	46.	45.	38.	39.	43.	56.
	9 P. M.	77.	53.	59.	71.	61.	63.	70.
Direction and Velocity of Wind	7 A. M.	S. 6	W. 11	N. W. 9	S. W. 4	N. W. 11	N. W. 7	N. 9
	2 P. M.	S. W. 13	N. W. 20	N. W. 4	N. W. 9	N. W. 2	N. E. 11	S. E. 6
	9 P. M.	S. W. 15	N. E. 13	S. E. 5	N. 6	S. 2	N. W. 1	S. 1
Velocity in feet per minute of air entering Ward, at a point 4 inches from centre of Register	7 A. M.	273	221	315	198	210	311	279
	2 P. M.	364	323	322	256	213	240	281
	9 P. M.	246	248	267	292	270	283	252
	Daily mean.	294	264	301	248	231	278	247
Hourly supply per bed		8829	7920	9039	7459	6930	8340	7419
Temperature of air entering Ward	7 A. M.	76.2	92.7	94.8	119.1	86.2	80.8	103.
	2 P. M.	87.3	112.1	86.4	112.9	79.1	83.2	85.1
	9 P. M.	84.3	84.7	103.5	92.5	84.4	108.3	83.1
Temperature of air at floor of Ward in centre	7 A. M.	65.	70.	67.	69.	63.	63.	69.
	2 P. M.	67.	69.	65.	65.	66.	66.	69.
	9 P. M.	69.	69.	65.	63.	63.	65.	64.

5

Temperature of air at head of beds	7 A. M.......	69.	70.	66.	71.	68.	68.	68.
	2 P. M.	69.	69.	69.	69.	68.	69.	68.
	9 P. M.......	70.	69.	69.	67.	69.	69.	67.
Temperature of air in ridge, Ventilating Chamber...	7 A. M.	83.	82.4	73.	90.6	79.	82.6	78.6
	2 P. M.......	77.8	81.	85.8	90.2	83.8	85.6	82.4
	9 P. M.......	81.4	78.6	89.	82.6	82.8	78.	80.4
Velocity of air in outlets in ceiling	7 A. M.......	103	.93	97	87	92	91	87
	2 P. M.	88	87	99	88	70	93	84
	9 P. M.......	100	81	81	84	103	83	88
Volume of air discharged per hour		296,238	265,698	271,197	263,651	269,759	271,806	263,651
Volume of air entering Ward per hour by Registers.		230,714	192,637	233,797	197,114	173,880	206,077	207,194
Estimated consumption of coal per hour, lbs*		23.21	21.41	40.07	21.41	28.57	32.14	28.57

* Estimated by weighing condensed water from return steam pipe.

OBSERVATIONS FOR DECEMBER 31, 1877.

Daily mean of Barometer		29,444
External Temperature.	7 A. M.	24.
	2 P. M.	36.
	9 P. M.	22.
Relative Humidity	7 A. M.	87.
	2 P. M.	39.
	9 P. M.	58.
Direction and Velocity of Wind.	7 A. M.	N. 16
	2 P. M.	N. W. 18
	9 P. M.	N. W. 20
Velocity in feet per minute of air entering Ward, at a point 4 inches from centre of Register.	7 A. M.	307
	2 P. M.	269
	9 P. M.	279
	Daily mean.	285
Hourly supply per bed		9560
Temperature of air entering Ward	7 A. M.	105.
	2 P. M.	105.
	9 P. M.	104.
Temperature of air at floor of Ward in centre	7 A. M.	63.
	2 P. M.	65.
	9 P. M.	63.
Temperature of air at head of beds	7 A. M.	68.
	2 P. M.	70.
	9 P. M.	68.
Temperature of air in ridge Ventilating Chamber	7 A. M.	78.
	2 P. M.	82.
	9 P. M.	80.
Velocity of air in outlets in ceiling	7 A. M.	98
	2 P. M.	98
	9 P. M.	101
Volume of air discharged per hour		302,346
Volume of air entering Ward per hour by Registers		302,346
Estimated consumption of Coal per hour, lbs		48.21

For Air Analysis of this date see page 69.

RECORD OF OBSERVATIONS

On Heating and Ventilation, made at the Boston City Hospital during the week ending January 12, 1878.

Day of the Month of January		6	7	8	9	10	11	12
Daily mean of Barometer		30.10	30.43	30.66	30.45	29.75	29.17	29.93
External Temperature	7 A. M.	12.	6.	2.	23.	32.	34.	37.
	2 P. M.	21.	13.	13.	35.	38.	37.	44.
	9 P. M.	14.	5.	17.	31.	42.	46.	40.
Relative Humidity	7 A. M.	61.	76.	67.	73.	84.	95.	63.
	2 P. M.	36.	36.	62.	49.	91.	90.	37.
	9 P. M.	64.	50.	83.	79.	100.	76.	65.
Direction and Velocity of Wind	7 A. M.	S. W. 8	W. 6	N. W. 6	S. 4	N. 4	W. 12	N. W. 24
	2 P. M.	W. 7	N. W. 16	S. E. 5	N. E. 3	N. E. 17	S. W. 14	N. W. 20
	9 P. M.	N. W. 8	N. W. 6	S. 10	S. 2	N. E. 40	N. W. 15	N. W. 20
Velocity in feet per minute of air intering Ward, at a point 4 inches from centre of Register	7 A. M.	240.26	211.66	170.76	224.26	178.97	132.42	151.38
	2 P. M.	261.22	187.60	204.54	218.78	242.83	147.63	166.30
	9 P. M.	209.04	214.76	192.85	227.64	247.52	160.16	137.47
	Daily mean.	236.84	204.67	189.38	223.56	223.10	146.73	151.71
Hourly supply per bed		7,105	6,140	5,681	6,706	6,693	6,602	6,826
Temperature of air entering Ward	7 A. M.	102.	111.	108.	120.	95.	85.	95.
	2 P. M.	114.	118.	109.	109.	109.	85.	91.
	9 P. M.	115.	121.	122.	89.	103.	90.	86.
Temperature of air at floor of Ward in centre	7 A. M.	53.	63.	65.	64.	65.	67.	67.
	2 P. M.	64.	63.	61.	68.	64.	64.	66.
	9 P. M.	64.	66.	64.	64.	64.	69.	68.

RECORD OF OBSERVATIONS—Continued.

Day of the Month of January................		6	7	8	9	10	11	12
Temperature of air at head of beds.........	7 A. M.......	57.	67.	67.	70.	68.	69.	70.
	2 P. M.......	69.	68.	67.	72.	70.	71.	71.
	9 P. M.......	68.	70.	70.	68.	71.	71.	69.
Temperature of air in ridge, Ventilating chamber..................................	7 A. M.......	73.	80.	69.	81.	78.	81.	83.
	2 P. M.......	86.	80.	77.	94.	87.	89.	83.
	9 P. M.......	87.	77.	83.	78.	84.	87.	82.
Velocity of air in outlets in ceiling.........	7 A. M.......	101.40	97.	338.91	......	268.83	97.53	91.40
	2 P. M.......	112.60	103.26	318.91	122.83	143.75	91.73	105.93
	9 P. M.......	71.80	342.41	1541.66	124.50	140.86	106.53	103.20
Volume of air discharged per hour..........................		292,756	260,094	199,799	377,657	434,584	307,201	305,919
Volume of air entering Ward per hour by Registers.....		198,945	171,922	159,079	187,790	187,404	184,798	191,154
Estimated consumption of coal per hour, lbs*.............		51.19	60.71	52.33	40.47	27.38	....	....
Relative Humidity in Ward..................	7 A. M.......	23.	22.	20.	35.	24.	40.	33.
	2 P. M.......	18.	18.	18.	29.	33.	32.	26.
	9 P. M.......	18.	17.	27.	29.	32.	26.	39.
Relative Humidity in Ventilating Chamber	7 A. M.......	9.	69.	8.	25.	44.	37.	22.
	2 P. M.......	41.	39.	13.	46.	33.	47.	33.
	9 P. M.......	41.	39.	26.	48.	20.	27.	23.

* Estimated by weighing condensed water from return steam pipe.

EXAMINATION OF AIR

For Carbonic Acid showing per centage by volume. By Professor Edward S. Wood, M. D.

1877, December 31st, 2 P. M.

Outer Air	0.04023
In centre of Ward at floor	0.06448
In Ventilating Chamber over Ward	0.07305

1878, January 5th, 2 P. M.

Outer Air	0.0332
Inner Air, 3 feet from floor in centre of Ward	0.0500
Air in Ventilating Chamber	0.0722

1878, January 12th, 2 P. M.

Outer Air	0.0421
Inner Air at floor midway between two windows and head of bed	0.0479
Inner Air 3 feet from floor in centre of Ward	0.0460
Inner Air 12 " " "	0.0677
Inner Air 12 feet over and 3 feet in front of window	0.0660
Air in Ventilating Chamber over Ward	0.0827

The facts set forth in the reports of Dr. Huntington and of Dr. Cowles, are of much interest and importance to all who are interested in the subject of Hospital Heating and Ventilation, and merit a much more extended discussion than would be justifiable within the limits of an advisory report like this. I will confine my remarks to the calling attention to a few points of special interest in this connection.

First, as to cost of heating. It is a little difficult to make the comparison, because in the Boston Hospital we have the data for one ward only, including about 45,600 cubic feet of space, while in the Barnes Hospital the large

central service building is also heated, making the total number of cubic feet heated over 300,000. If we take the number of cubic feet of air heated per hour from an average temperature of 38° F. to 70° F., we find that in the Boston Hospital it was about 220,000 cubic feet, and in the Barnes Hospital about 800,000 cubic feet—taking the average velocity in the main air duct with its area of 40 square feet at 330 feet per minute. To effect this, the consumption of coal in the Boston Hospital was 25 pounds per hour, in the Barnes Hospital about 70 pounds per hour. The Barnes Hospital heating apparatus, therefore, has nearly four times as much work to do as that of the Boston Hospital, and it does it with about three times the quantity of coal.

Second, as to the results produced. In the Boston Hospital the amount of air supply per patient is in round numbers about two feet per second per bed. In the Barnes Hospital it is about one and a half feet per second per bed in the ward. Yet the results of the first chemical analyses made show about the same percentage of impurity in the Boston wards as in the Barnes wards.

This fact seemed to prove that the distribution and diffusion are not what they should be in the Boston Hospital, and that probably a very considerable proportion of the fresh air introduced escaped at the ceiling, without thoroughly mixing with and diluting the foul air in the room. Upon this being suggested to Dr. Cowles, he made the second series of experiments above referred to, and also other experiments, to test direction and velocity of currents in the room by means of smoke, etc. The results show a very excellent diffusion of the fresh, and dilution of the foul air, but there is no doubt that a certain portion of the fresh, warm air passes directly from the inlets to the outlets. The results obtained by Dr. Wood in his air analyses of January 5th and January 12th, are very remarkable, so much so, in fact, that I cannot place any very great weight upon them without further confirmation. I have not the slight-

est doubt as to the accuracy of the analyses, but I do not believe that in a ward fully occupied by sick men, and supplied with fresh air only by registers at the sides, the air in the centre of the room would contain only 0.0039 more carbonic acid than the outer air, if thorough diffusion were taking place. With the amount of air entering the ward, had it been thoroughly distributed, the percentage of carbonic acid should have been about 0.05, as in the analysis of January 5th.

It is not easy to explain the different results obtained in the three analyses, but it is evident that a much larger number would be necessary to obtain positive conclusions.

If the minimetric process of Lunge* shall prove on trial to be sufficiently accurate for practical purposes, it will make such observations comparatively easy, and I hope this will prove to be the case, since this is, after all, the only scientific test as to sufficiency of ventilation.

The third point to which I invite attention is the great variation in amounts of air supply in each Hospital at different times as shown by anemometrical measurements, depending on external temperature, winds and humidity. The probable limits of error in a single observation are evidently so wide that it can give little information, and even a week's work can hardly be considered as giving enough data for accurate comparison.

Dr. Huntington thinks that a year's trial and records are needed to judge fairly of the relative merits of the heating and ventilation of the two Hospitals.

Attention is invited to the low relative humidity in the Boston ward.

It is much lower than in the Barnes Hospital, and lower than it ought to be for comfort, but no complaints are made of ill-effects.

*Zur frage der Ventilation mit Beschreibung u. Abbildung des minimetrischen Apparatus zur Bestimmung der Luft Verunreinigung, von Dr. Georg Lunge. Zurich, 1877. 8°.

The last point to which I invite special attention is the statement of Dr. Huntington upon the value of the fan as a means of control and assistance to systems of aspiration, and for the purpose of deluging the wards with a large quantity of fresh air.

Its power to do this is well shown in the experiment referred to in the account of the chemical analysis in ward D, where by the use of the fan for ten minutes, the volume of carbonic acid was reduced from 11.23 per 10,000, to 3.75 per 10,000.

I cannot close this part of my report without returning thanks to Drs. Huntington, Cowles, Wood and Mew for the trouble they have taken to obtain these data. Few as they are, they are the best collection of such observations ever made in this country, and it is greatly to be desired that they should be continued, and that the superintendents of other Hospitalsd should make similar observations.

If we only had a year's careful observations from the Massachusetts General Hospital: the Presbyterian, Roosevelt and New York Hospitals of New York: the Presbyterian, Episcopal and University Hospitals, of Philadelphia: the Cincinnati Hospital, and the Cooke County Hospital of Chicago, similar in character to those above given, we should have the data for a treatise in Hospital heating and ventilation that would be really valuable and useful.

The various recommendations on this subject which we now have, come mainly from the depths of the internal consciousness of some highly estimable gentlemen who would no doubt warmly welcome such a collection of facts as I have above referred to, but who have endeavored to do the best they could without them, since they are not to be obtained without some expense and much skilled labor. It should be clearly understood that such observations are not easily made, nor can they be entrusted to an average Hospital attendant. Anemometrical observations especially require great care and many repetitions to make them trustworthy. If taken in front of a register they are un-

trustworthy, unless the register openings are uniform in size and shape, and even then the particular co-efficient of the register must be ascertained.

The climate of Baltimore differs little from that of Washington, and the character of buildings in this Hospital, and their relative exposure to winds, will be much the same as in the Barnes Hospital. The amount of cubic space to be heated when all the buildings are erected, will be about 3,000,000 cubic feet, or ten times that of the Washington building, and the amount of air supply required will be about eight times that demanded at the Barnes Hospital. I infer, therefore, that 1600 tons of coal annually may be provisionally taken as a reasonable cost, for heating and ventilating the buildings of this Hospital, when fully occupied, in such a manner as to secure at all times the comfort of the occupants, and purity of the air to the standard fixed, *i e.*, that the percentage of carbonic acid when gas is not burning shall not exceed six parts per 10,000, and this estimate is confirmed by an examination of the amount of fuel consumed in several of the largest and best Hospitals of this country.

This is not by any means the first time that an attempt has been made to secure satisfactory heating and ventilation in a Hospital of this size and character, but complete success has been the exception rather than the rule.

From personal examination of the methods employed, and results obtained, in the principal Hospitals in this country and in Europe, I would divide the causes of the many partial failures into six classes.

1st. To the want of proper arrangements to prevent unnecessary contamination of the air. Unnecessary contaminations are due to sewer gases, illuminating gas, want of cleanliness, improper treatment of wounds and ulcers, and to improper plan of buildings by which the air from one ward or room passes into another.

2nd To insufficient areas of flues, both for fresh and foul air.

3rd. To want of proper arrangements of flues and registers to secure a speedy and thorough distribution of the fresh incoming air, so that there may be a constant and uniform dilution of that which is impure. It happens too often that direct currents are established between inlet and outlet openings, so that in large portions of the room the rate of change is entirely insufficient, although a sufficient quantity of air is passing through it.

4th. To the fact that the power of the wind to interfere with systems of ventilation is too often forgotten, and therefore provision is made for only one condition of things. The same system of heating and ventilation which will give good results with a gentle breeze from the southwest, may work very badly in a gale from the northeast. Ventilation becomes most difficult when the air is motionless, and saturated with moisture, and the temperature is high.

5th. To want of application of the apparatus which the Architect and Engineer have provided, owing partly to carelessness, and in part to the desire to reduce the consumption of fuel. It is on this last account that I have found fans standing still and rusting, aspirating chimneys doing hardly 20 per cent. of the work for which they were designed, and therefore liable to reverse currents—and outlets and inlets more or less closed.

6th. To the want of intelligent, careful and continuous supervision.

This kind of supervision is absolutely necessary, and I have found it present in every case of successful heating and ventilation of any but the smallest and simplest Hospitals.

Undoubtedly, it is very desirable that a ventilating apparatus shall be automatic in its action as far as possible, and the possibilities are very great,—a ward can be so arranged that its temperature, moisture and amount of air supply can be kept very nearly at a fixed point, no matter what the external conditions may be, and this by machi-

nery only,—but here comes in the question of expense,—and for such a complicated series of buildings as this Hospital presents, the expense would not be trifling, nor would the apparatus work well without frequent intelligent supervision.

I have in a previous report referred to the advisability of varying to some extent the systems of heating and ventilation in the wards, and of not employing any one system alone at first. I would now reiterate this recommendation, and for the following reasons:

I. I am not sufficiently assured of the superiority of any one system of minor details above all others to be willing to recommend its exclusive adoption. I have never seen any system of heating and ventilation in actual use that could not in some way be improved, and I do not think it probable that the system to be employed in this hospital will be an exception to the general rule.

II. I think that by careful and scientific trial of several different systems this hospital will be able to settle with a fair degree of precision, some of the vexed questions with regard to relative efficiency and economy of various plans, and this at a comparatively small expense. This would be one of the most important contributions which this institution can make to our knowledge of Hospital hygiene, and its decision of the matter can be made authoritative.

III. This hospital is to contribute, among other things, to education—and among the things which it is to teach is sanitary construction of buildings, such as those it contains, and it can present a fair variety. Now to teach effectively it should be able to show various methods and their results: it should be a sort of laboratory of heating and ventilation.

IV. This variety can be secured at comparatively small expense. The buildings are so large and numerous that several boilers will be needed—and a part of these can be for steam, and others for hot water. We must have at least one steam boiler for working an engine, in any event.

So far as ducts and registers are concerned they are not expensive, and they can be shifted above and below the wards to almost any extent, when the most satisfactory distribution has been determined. In order to facilitate experiments and observations upon the working of the ventilating apparatus, care should be taken that in all important ducts, flues and chimneys, means of access to the interior are provided, so that anemometers, thermometers, etc., can be conveniently introduced and observed. The only expensive means of ventilation which I wish to see provided, is one in which my confidence has steadily increased since I first investigated its operation and effects, and that is the propelling fan.

The Fan in Ventilation.

In regard to the value of the fan as a means of impulsion of air, and especially when combined with the ordinary systems of aspiration, as giving complete and precise control of the matter at all times, I would invite special attention to the remarks of Dr. Huntington. The power of "blowing out" the ward rapidly, as he phrases it, is a very valuable one.

In the Barnes Hospital the fan has the special advantage of a straight duct and will give a greater result from a given quantity of fuel than can be expected in our Hospital. To show, however, that angles in ducts, and distance do not destroy the power of a good fan, I will refer to a series of observations made at my request by Dr. Huntington and Dr. Robert Fletcher upon the working of the fan at the Government Asylum for the Insane, near Washington. This fan is 12 feet in diameter, and was running at 80 revolutions per minute. The mean velocity in the main duct leading from the fan was about 850 feet per minute, and the area being 60 square feet, the delivery was 850 feet per second. At a point, 475 feet from the fan, where by giving off of branches the area of the duct was

reduced to 30 square feet, the velocity was 900 feet per minute.

At the extreme east end of the building, and at a height of two stories about 840 feet from the fan, and after the passage of several right angles in the ducts—the velocity at the register openings was 150 feet per minute, or over 2 feet per second. It is very evident, therefore, that this fan is fully competent to do the work required of it at a greater distance and with more angles than would be presented in this Hospital.

In connection with the effect of angles and bends in the fan ducts, I would call attention to results obtained by the use of the fan which supplies fresh air to the Hall of the House of Representatives at Washington.

Through the courtesy of Mr. Edward Clark, the Architect of the Capitol—a series of observations upon the working of the heating and ventilating apparatus of this hall were made at my request during the months of November and December, 1877.

The fan used is 16 feet in diameter, and the duct leading from it has an area of 75 square feet. This duct has several angles and bends in it, but it is easy by the use of the fan to obtain any velocity from 360 to 900 feet per minute in it, corresponding to a delivery of from 22,500 to 67,500 cubic feet of air per minute, with a maximum velocity of 100 revolutions per minute.

Farther details with regard to the working of this fan will be found in a report on the ventilation of the House of Representatives, 45th Cong., 2nd session. Report No. 119.

I do not think it is necessary to discuss farther, or to point out in detail, the advantage to this Hospital of possessing means for the mechanical impulsion of air in addition to, but by no means to the exclusion of, the ordinary aspirating systems. I am of the opinion that a good fan, with properly arranged ducts, will be an exceedingly valuable addition to the means of ventilating this Hospital, will give complete control of the air supply at all times,

and will make the system as nearly perfect as can be done at a reasonable cost. Such a fan and engine will cost about $1,000. The engine will be run by the high pressure boiler which is to be provided for other purposes. The main item of expense will be the construction of the proper ducts. The maximum expense of these ducts will be $15,000.

I would strongly advise that the necessary arrangements be made for these ducts in the work which is to go on during the coming summer, for I feel certain that if this be not done it will be regretted, since sooner or later such a system will be found so desirable that it will probably be introduced, although at a much greater cost than would be required at present.

As to the particular form of impelling power to be furnished, I would submit the following considerations:

The amount of air required for flushing purposes is 600 feet per second, or 36,000 feet per minute. The best velocity to maintain in the main duct is, so far as my experience goes, about 10 feet per second. This would fix the area of this main duct at about 60 square feet.

If a fan similar in character to that in use at the House of Representatives be employed, the best size would probably be about 10 feet in diameter. Such a fan requires a delivery duct of 62.8 square feet, and a supply duct of an area of 78.5 square feet will, according to Mr. Briggs's data, deliver about 40,000 cubic feet of air per minute at 100 revolutions per minute against a pressure of about 0.3 inches of water column.*

Such a fan, connected with a fifteen horse-power engine, would certainly do all the work required even against a resistance of over one inch of water pressure.

According to the same authority, a fan 8 feet in diameter running at about 200 revolutions per minute, would also furnish the amount of air required, but I should prefer the larger size with less velocity.

*"On the conditions and the limits which govern the proportions of rotary fans," by Robert Briggs, London, 1870.

As the supply duct from such a fan need be only 40.2 square feet area, it may possibly be found in working out details of plans that such a duct can be more conveniently placed than one of a larger size, but the velocity of the air in it must be 15 feet per second, and the friction will increase correspondingly. The same remark applies to all varieties of propelling apparatus, which are calculated for small ducts. The special objection to the use of what are called "blowers," such as the Root or Sturtevant blower, for hospital ventilation, is the noise that they make. They are calculated to work against much greater pressure than the fan, and with smaller ducts and increased velocities.

The fans above referred to are of the pattern known as the Combe's fan. Some good engineering authorities are of the opinion that what is known as the Rittinger fan produces a greater percentage of effect in proportion to the power applied, but I have never had the opportunity of investigating the working of such an apparatus.

I do not attach so much importance to the particular form of fan or other propelling apparatus to be employed as I do to the arrangement and sizes of the ducts, and it is owing to errors in such arrangement that every case of failure of such a system that I have seen has arisen.

It cannot be too strongly insisted on that the plan of the ducts should be arranged first, and the size of the fan be proportioned to them afterwards. If the area of delivery of the fan be either larger or smaller than that of the main duct there will be loss of power. In the smaller ducts the velocity of the air should steadily diminish as they branch off. Suppose we start with one main duct from the kitchen building with an area of 63 square feet. This main duct is to give off two lateral ducts, one to the North and one to the South corridor. These can go off on an easy curve, the radius being about 20 feet, and the duct for the North corridor should have 38 square feet, and that for the South corridor 40 square feet of area. The first duct which the North corridor duct gives off is to the two-story octagon

ward—having 48 beds to supply with two cubic feet per second. The area of this duct should be 12 square feet—giving a velocity of eight feet per second. Each heating coil in this building supplies four beds, and the area of the terminal duct to a coil should be two square feet—the velocity in which would be four feet per second.

After giving off the octagon ward duct the main duct should be reduced to 30 square feet area. The duct for each common ward should have an area of 8 square feet, and the area of the main duct after giving it off should diminish 6 square feet. The terminal duct passing to the Isolating ward would therefore have an area of 10 square feet. In the common wards each heating coil supplies two beds, and its fan duct should have an area of one square foot.

The duct in the South corridor will be distributed in the same way. In no case should one duct leave another at a right angle, and at each point of intersection should be placed a hinged valve so that more or less air can be directed into either duct. At convenient points upon the ducts should be small openings with doors closing air tight, through which an anemometer can be conveniently introduced when desired. Within the duct leading from the fan, and at a point about 25 feet from it, it will be easy, and will cost very little, to place a ring of water pipe perforated in such a way that at pleasure a sheet of spray can be produced for washing, moistening and slightly cooling the air. To make this available in cold weather for adding a small percentage of moisture to the air, the air must be warmed a little before passing it through the spray, and this can perhaps be best effected by placing a coil in the supply duct of the fan, which coil could be supplied by the exhaust steam from the engine. Farther discussion as to details of the fan system is postponed until the drawings required to make it intelligible are prepared.

The Trustees having decided to obtain the Heating and Ventilating Apparatus for the Hospital from Messrs. Bart-

lett, Robbins & Co., of Baltimore, I have consulted with the engineers of this firm, viz: Mr. T. J. Hayward and Mr. C. W. Newton, who agree with the general propositions contained in the preceding part of this paper.

In what follows, I give the joint conclusions of Messrs. Hayward, Newton and myself as to some of the details, reserving complete specifications and working drawings, for a future paper.

Details of Heating and Ventilating Apparatus.

The Main Administration Building, with its annex the Apothecaries Building, the Nurses Home, the Superintendent's Residence, the Kitchen, and all the wards will be heated by hot water, low temperature. The Dispensary, Amphitheatre, and Bath Houses will be heated by steam, low pressure.

The Laundry, and the Pathological Building, will each have their own heating apparatus.

While we are satisfied that hot water will furnish the most satisfactory and economical means of heating the buildings in which its use has been above recommended, we think that if it be desired to compare the effects of low pressure steam heating in a ward with those of hot water, there is no serious objection to doing so, by so arranging the heating apparatus in one of the wards, that either low pressure steam or hot water can be employed in it at pleasure. To do this will entail additional expense, however, and we do not recommend it.

To effect the heating, eight horizontal flue hot water boilers, each five feet in diameter, and 16 feet long, and one low pressure steam boiler of somewhat less dimensions will be required.

Four of the hot water boilers will be placed in the cellar of the Nurses Home—the other four, together with the steam boilers required, will be placed in a vault just outside the kitchen. It is possible that to obtain the best ar-

rangement of space the dimensions of the boilers may be varied somewhat, but the amount of surface will correspond with that above indicated.

But two hot water boilers will be required, at present, in the Nurses Home, and these will be connected with two of the hot water boilers in the kitchen vault, which must therefore be arranged on the same level. From this circulation will be heated the main building and its annex, the two pay wards and the Nurses Home. The flow pipes of this system will be on a level of about 105 feet above tide, and the return pipes at 100 feet above tide, and both sets of pipes will therefore be placed in a tunnel running underneath the west corridor, the flow of which is 114 feet above tide. By this arrangement it will be possible, for the greater part of the time, to heat all this circulation from the kitchen boilers only.

Two of the hot water boilers in the kitchen will be devoted to heating the wards and service buildings on the north of the Central Garden. The flow pipes from these will be situated in the corridor, and at a height of about 122 feet above tide: the return pipes will be in the tunnel beneath the corridor, at a height of about 113 feet above tide.

A similar pair of boilers, with similar connections, will be placed in the Nurses Home, when the wards on the South of the lot are built.

The ventilation of each building will be effected under ordinary circumstances by open fireplaces, aspirating chimneys or ridge ventilators, as will be explained in speaking of the several buildings, and the ventilation of each building will be kept entirely separate from that of all others.

For accelerating ventilation—high pressure steam coils are to be used in the aspirating shafts or boxes, and a fan, ten feet in diameter with suitable ducts, is to be provided, as specified in the preceding part of this report. The power for this purpose, and also for pumping, etc., will be derived from two high pressure boilers, placed in

the vault of the kitchen building. These boilers will also heat the hot water reservoirs connected with bath rooms, lavatories, etc., in each building.

We will now state briefly the arrangements proposed for the several buildings:

1. The Administration Building.

I. This is to be heated by hot water and by open grates or fireplaces in the several rooms, which last are also to act as foul air flues. The hot water coils, are placed in the basement, which is 13 feet high, six feet being above ground. The fresh air to supply these coils will be taken from the windows in a way not easily to be explained without a drawing, but of which it may be asserted that while giving an abundant supply of fresh air, it will not be perceptible externally, except on close examination.

The coils are set against partition or outer walls, have brick walls at the ends, and in front a door of galvanized iron, hollow and packed with felt. By the removal of this door, the whole of the coil is readily accessible for cleaning, etc. From the coils, flues pass to the various rooms, the average size of flues being 9x14 inches. These flues will be made of galvanized iron, set in the brick walls, and where they come in outside walls, they will have an air space on all except the inner side. This description of coils and flues will apply to all the buildings in which hot water is used for heating. Each room has its own fresh air flue or flues, and, as far as possible, each coil sends flues to one story only. Each room has also its own fire-place and chimney-flue.

All water-closets, bath-rooms, etc., for the use of the occupants of this building are placed together in a rear projection behind a cross corridor, and a separate ventilating shaft, 2 feet in diameter, is provided to ventilate them. The driving power for this shaft is to be a line of steam pipe placed in it. The gas jets when in use will also be

used for this purpose. As this building will be occupied only by persons in health, and has no dining rooms, medicines, or other sources of unpleasant odors in it, its heating and ventilation is even a simpler matter than that of a first-class private dwelling, and it is believed that the plan proposed will give satisfactory results.

II. The Pay Wards.

The heating of these buildings is to be partly by direct, and partly by indirect radiation. Each patient has a separate room, and each room has an open fire-place, which will be relied on for heating, except in very cold weather. Arrangements are made for hot water coils in the basement, with flues to each room, very much as in the main building just referred to. The basement will have a concrete floor, plastered ceiling and white-washed walls—will contain nothing but the heating coils, and will be inaccessible, except to the engineer. During the greater part of the time it will be freely open to the outer air by means of its grated windows, and will furnish the air supply to the coils. During cold weather the fire-places in the several rooms will give all the ventilation necessary, but when a fire on the hearth would be uncomfortable, ventilation can be effected by flues on the inner or corridor walls, which flues pass up to a foul air box in the attic. In this box will be placed an accelerating steam coil, and from it a shaft will lead obliquely upwards to the central ventilating shaft which is capped by a ventilator. When these flues are working, the throat of the fire-place will be covered by a soap stone slab. The supply of fresh air required for these buildings will be from forty to sixty cubic feet per second to each.

III. The Common Wards.

The common wards rest on basements about ten feet high, entirely above ground. These basements will have concrete floors, plastered ceilings, and white-washed walls, and will contain nothing except the apparatus for heating and ventilation. The doors leading into them from the corridors will be made air-tight, and these basements can safely be used as air chambers, from which the supply for the heating coils can be taken when, by reason of winds, the pressure on the external walls are unequal. The supply can also be taken directly from the external air. In either case it is desirable, although not essential, that the ducts be so arranged that the fresh air can be admitted without having to pass through the coil. It is not essential, as it would be with steam heated surfaces, because by means of the cut off valve to be provided at each coil, the circulation in the coil can be reduced to any extent, and its temperature lowered to correspond. But the changes in external temperature in this vicinity are rapid in the Spring and Autumn; and when the coil is entirely cut off it will be at least half an hour before it has cooled to the external temperature, so that the comfort of the patients will be promoted by furnishing the means of rapidly altering the temperature of the incoming air, although they cannot change the quantity delivered.

This may be effected in several ways; one of the simplest of which is shown in Fig. 1, which represents a section of a heating coil, with the flues connected with it.

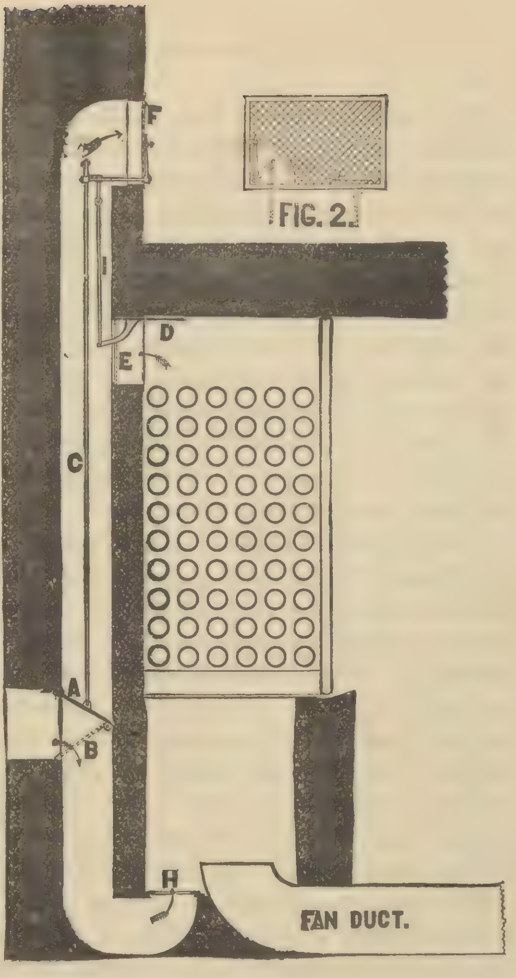

FIG. 2.

FIG. I.

A is a valve, which is worked from the fresh air register F, situated in the Ward. The front view of this register is shown in Fig. 2.

By moving the valve A, the fresh air coming in through an opening in the external wall can be directed through the duct B to the heating coil, or through the duct C outside the heating coil.

The valve D closes the opening E from the heating coil into the flue.

The sliding valve H regulating the flow of air is controlled by the engineer only.

The arrangement of the fan duct, is such as to exert an aspirating force on the duct B.

The valves A and D are moved by locked rods under the care of the nurse.

Under the rectangular wards a heating coil, arranged as above, stands between each pair of windows. From the space between the top of the coil and the ceiling two flues pass up. The first, shown in the figure, measuring 9 by 22 inches, passes in the centre of the pier and opens in the wall at a point ten inches above the floor, and between the beds. The other passes obliquely from the end of the coil, and opens beneath the window in the ward. This last flue is 9″x14″, and its register will be filled with movable louvres, so that the patients can close it at will. This flue will not be used except in cold weather, with a moderately strong wind.

The register to the flue in the pier will have no means of closure, but the flue itself can be closed at its point of exit from the coil. This valve is under the control of the engineer or head nurse only.

Each of the rectangular wards has a separate aspirating shaft which stands on the central longitudinal axis of the building, in an octagonal hall or vestibule on the corridor just outside the ward.

Into this shaft empties the foul air duct which runs longitudinally beneath the floor of the ward, and which receives the air from lateral ducts opening beneath the foot of each bed. These ducts will be made of galvanized iron and suspended from the ceiling of the basement. They will be so arranged that they can be thoroughly cleansed throughout.

The area of opening under the foot of each bed will be 100 square inches, of each lateral duct from about 80 square inches to 100 square inches. The larger diameter is requisite in those ducts at the end of the ward most remote from the aspirating shaft. The area of the main foul air duct increases from about two square feet to eight square feet at the point at which it enters the chimney. The chimney is an octagonal shaft, rising to a height of 35 feet above the level of the ward floor, and will contain

a steam coil. The general arrangement proposed is shown in Figures 3 and 4.

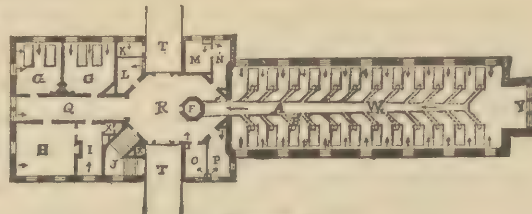

Figure 3.

Figure 3 is a floor plan of one of the wards.

A is the foul air duct beneath the floor leading to the aspirating chimney F.

At the end of the ward Y is a large bay window, looking on the central garden. Underneath this window will be a small coil for direct radiation.

M, water-closets. N, lavatory. O, bath-room. P, nurses' closet. R, octagonal vestibule, with fire-place. T, open terrace walk above connecting corridor. G, private rooms. H, dining-room. I, kitchen. K, linen room. L, patients' clothing.

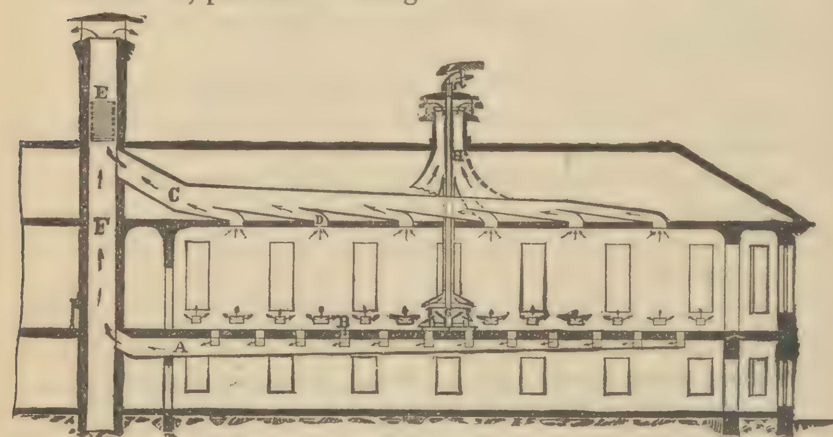

Figure 4.

Figure 4 shows a longitudinal section of the ward.

A is the foul air duct beneath the ward.

C is a similar duct above the ceiling, also opening into the aspirating chimney, F.

The position of the steam coil is shown at E.

Figure 4 also indicates another method of ventilation by means of a double open fire-place in the centre of the ward, with additional flues and registers above the ceiling. If this were used the duct leading to the chimney would of course be omitted.

Another method would be to carry up boxed openings from the centre of the ceiling to the apex of the roof, where they would terminate in ventilators. Two such openings, each ten feet long and two feet wide, would be required, and the boxes should be arranged with valves and accelerating steam coils as in the one story wards of the Boston City Hospital.

Direct radiation in the wards can be most conveniently provided by a double open fire-place standing in the centre of the ward, the pipe from which should pass directly upward through the roof, which can easily be effected where the ridge ventilating boxes are used, but would be more difficult if a longitudinal foul air duct is to be carried above the ceiling. Such a double fire-place may be made of iron, soap-stone, or covered with porcelain or terra cotta. To avoid noise, dirt and danger, and the inconvenience of occasional defective draught and smoking which will sometimes happen, it may be worth while to try in these fire-places the substitution of a steam coil with reflectors, for the open fire. Nothing about the fire-place or smoke flue should be altered to affect this, for all the air which passes over the coil should pass up the smoke flue—precisely as in the fire-place. Direct radiation will be provided in the alcove at the south end of the ward and an open fire-place is placed in the vestibule in connection with the aspirating shaft, and this will probably be the only one actually desirable.

It will be perceived that the construction of these wards permits of much variety in the arrangement of ducts above and below them, and that changes can be readily made at small expense. For reasons before given it is recom-

mended that the methods to be first tried, vary in each of the three wards now to be built. It is not believed that the results will be found to differ much, but if such should prove to be the case, all the wards can be made uniform with that which proves the best.

The Octagon ward is planned for a system of central ventilation by a large chimney with which fire-places may be connected, very much as is the square wards of the Massachusetts General Hospital. As there are two stories of wards in this building, the heating flues cannot be so conveniently arranged as in the other wards. There will be but one heating flue to two beds, and this will open in the outer wall beneath the windows. The foul air will be taken off at the centre of the room, at the floor or ceiling at pleasure, and pass directly into the aspirating shaft.

The details of the isolating wards have not yet been settled, but the system of heating and ventilation will probably not differ essentially from that proposed for the pay wards, except that provision will be made for a relatively larger supply of air.

IV. The Nurses Home.

This is a large building—90 feet square and four stories high, analagous in some respects to a hotel in its arrangements, and it will require especial care in its arrangements to produce a satisfactory result. The plan proposed for heating is to consist in the main of indirect radiation from heating coils placed in the cellar. In a few of the rooms fire-places are provided and these rooms will be used in cases of sickness.

In the centre of the building is a brick shaft, six feet interior diameter. Around this central shaft are arranged the water-closets and bath-rooms, with two large light shafts each 7″x11″ coming down from the top of the building. This central block is surrounded by corridors 9 feet wide, two of which, i. e. those running north and south, pass

from side to side of the building, terminating in large windows. Outside these corridors, and opening from them, come the bed-rooms of the nurses, each having a window in the outer wall. The prevailing winds being from south to north—will for the six warm months of the year sweep through the long corridor just referred to. It is evident that this will exercise a strong aspirating power upon all openings connected with the corridor, and that therefore all such openings into the central block should be avoided as much as possible. To this end the doors from the corridor should be made to close automatically and as nearly air-tight as possible, while the supply of air for ventilating the water-closets and other rooms should be taken from the light shafts. These light shafts will be capped by skylights raised about three inches from the roof, and will communicate at the bottom with the outer air by means of large horizontal ducts.

The basement of this building will be ventilated by means of large horizontal ducts passing to the base of the central chimney. During cold weather this chimney will receive the waste heat from the boiler fires; in warm weather a special fire will be maintained in a separate furnace, to produce the requisite aspirating force. On the three upper floors the ventilating flues pass upwards on the inside walls to the attic. In the attic they discharge into ducts of galvanized iron which empty into the central shaft. The water-closets and bath-rooms have separate pipe and ventilating shafts rising and discharging in like manner. Accelerating steam coils can be placed in the attic if desired, but they will probably be unnecessary.

In each bed room the inlets, outlets and flues are arranged for a supply of one cubic foot per second, with a velocity of two feet per second.

The system for this building will prove perfectly satisfactory, if at all times the temperature of the central shaft in the attic is not less than 20°F higher than that of the external air.

Even in warm days when all windows can be left open, it will not do to omit heating this shaft, for if this be not done the shaft will surely work backwards, and the results will be very disagreeable, though probably not specially dangerous.

The daily consumption of coal required for this purpose alone during the summer months will probably be between three and four hundred pounds.

The main building annex or apothecaries building is entirely separated from all other buildings, and with the corridor it only connects by a short covered passage open at the sides to the external air.

The main floor of this building contains the officers' dining-room and the apothecaries' establishment, and each of these is ventilated by a separate aspirating chimney placed at the east end.

The upper floors of bed-rooms for servants are ventilated by flues rising in the inner partition walls to the attic, where they gather into a box from which a cylindrical ventilating shaft passes upward through the roof. This shaft will be capped by an Emerson Ventilator.

This form of cap is considered to be quite as good as any of the numerous patent ventilating caps in the market provided it is properly made, and raised to such a height above the roof that the upward currents produced by the deflection of the wind from the sloping surface of the roof shall not interfere with it.

Other Buildings.

As the Dispensary and Amphitheatre are to be occupied but a few hours at a time, it will be found more convenient and economical to heat them by low pressure steam apparatus. In the dispensary direct radiation should be provided in part. As both these buildings are one story structures there is no difficulty in securing satisfactory ventilation. The amount of air supply required for each

will be comparatively large, and the heating surfaces will be proportioned to allow a supply of 150 feet per second.

The pathological building will be provided with its own heating apparatus, and will be ventilated by aspirating chimneys, but the details are not yet decided on.

With regard to the remaining buildings of the Hospital no special comment is needed now, as the plans are not yet completed—but their heating and ventilation will be arranged in accordance with the general principles above stated.

In conclusion, I would remark that the system of heating and ventilation recommended in this report is recommended for this particular Hospital only. Many of the general principles stated will apply to all Hospitals, but the methods of applying them may vary considerably, and the particular method here advised has been selected as suitable for this climate, for the peculiar location and plan of the Hospital, and to fulfil the several objects to be kept in view in its organization.

Very respectfully,

Your obedient servant,

JOHN S. BILLINGS,

Surgeon U. S. Army.

will be comparatively large, and the heating surfaces will be proportioned to allow a supply of 150 feet per second.

The pathological building will be provided with its own heating apparatus and will be ventilated by aspirating chimneys, but the details are not yet decided on.

With regard to the remaining buildings of the Hospital no special comment is needed now—as the plans are not yet completed—but their heating and ventilation will be arranged in accordance with the general principles above stated.

In conclusion, I would repeat that the systems of heating and ventilation recommended in this report are those intended for this particular Hospital only. Many of the general principles stated will apply to all Hospitals, but the methods of applying them may vary considerably, and the particular method here advised has been selected as suitable for this climate, for the peculiar location and plan of the Hospital, and so that the several objects to be kept in view in its organization.

Very respectfully,

Your obedient servant,

JOHN S. BILLINGS,

Surgeon U. S. Army.